In Search of the Perfect BoM

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ABSTRACT

OEMs turn to outsourcing to gain manufacturing efficiencies, but the efficiencies (and accompanying cost savings) they hope to achieve can be elusive. Some of the greatest obstacles are problems associated with bills of materials (BoMs). Supply chain interactions are seriously hindered by the lack of a standard data format for BoMs, unacceptably high error rates, and a lack of technology and tools to validate BoMs. The problems are pervasive, and the consequences, far-reaching. The cycles required to clarify or correct data can directly affect time to market and time to volume.

In 2001, the National Electronics Manufacturing Initiative (NEMI) organized a team of industry leaders to investigate and define the issues surrounding BoMs. This team is recommending a solution that calls for industry to adopt a common format with standardized contents — the "Perfect BoM" — to ensure that data is consistent, correct and complete, and that errors are resolved *before* exchanges are made among business partners. The team has identified the Product Data eXchange (PDX) specifications, developed by NEMI's Virtual Factory Information Interchange Project, as the foundation for the Perfect BoM. These specifications provide an industry-standard approach to exchanging BoM and change order information and will be used to define data structure. In addition, the team has developed a recommended list of data to define standard BoM content.

This paper discusses the problems and challenges that exist with today's BoMs, and outlines NEMI's recommended solutions for creating and implementing the Perfect BoM.

Key words: bill of materials, BoM, supply chain communication.

INTRODUCTION

The bill of materials (BoM) is, in its simplest form, a list of parts or components required to build a product. It provides the manufacturer's part number (MPN) and the quantity needed of each component. At its most complex, the BoM is a multi-level document that provides build data for multiple sub-assemblies (products within products) and includes — for each item — part number, approved manufacturers list (AML), mechanical characteristics and a whole range of component descriptors. It may also include attached reference files, such as part specifications, CAD files and schematics.

Originally used internally within a company, the BoM served as a means of tracking product changes and maintaining an accurate list of components needed to build products. As manufacturing has become increasingly distributed, the BoM has taken on even greater importance, serving as the primary reference file for product data. It is used to transfer product information from OEM to EMS provider and from the EMS to its vendors and suppliers. As outsourcing expands the number of companies involved in the manufacturing process, the need for accuracy is more critical than ever. At the same time, the transfer of manufacturing data across multiple companies magnifies problems and increases challenges.

As the primary conduit for data transfer among manufacturing partners, the BoM is central to the product life cycle from the very beginning. Figure 1 illustrates the flow of information from design to manufacturing. As indicated, a diverse set of information systems feed into the BoM, each providing different pieces of the information required to manufacture the final product. Typically, this wide variety of design, PDM and ERP tools output BoMs in different formats and at varying levels of completeness. File type and structure vary by company and, sometimes, even within a company, particularly if several groups have been merged into a single organization. This lack of standard format leads to redundant data processing.

EMS providers use parsers to "neutralize" data — i.e., convert it to a neutral format, such as a standardized text or XML file, that can be used by the EMS provider's tools. Parsers extract key data from customer data files and build a standard data format. Today, EMS providers must develop parsers and scripts for each different format received. One EMS provider reports that it maintains an internal organization of about 80 people whose function is to interpret customer data and translate it into their own production system.

DATA ERRORS / BOM DEFECTS

The most significant problem plaguing BoMs is errors. EMS providers report that the data received from their OEM customers is often incomplete, inconsistent and/or outright incorrect. One EMS provider told the NEMI Perfect BoM team that seven out of 10 customers consistently need BoM

corrections, and three in 10 components have bad or missing data. Several EMS providers said that error rates of 80% are not uncommon.

EMS providers are spending a great deal of time and resources correcting deficiencies in the BoMs they receive. Errors must be communicated back to the OEM for resolution, and valuable cycle time is lost. BoM errors typically fall within three categories: completeness, consistency and correctness.

Completeness
Incomplete data is the most common BoM defect. Critical pieces of information, such as quantity, part description, reference designation and approved manufacturers list, are often omitted. Missing AMLs reportedly cause the majority of problems.

Consistency
Information in the BoM sometimes conflicts with information provided in engineering drawings and design files. For example, quantities may not match — there may be 10 locations for a particular component indicated on a board, but only a quantity of nine components specified in the BoM. Another consistency problem is format. The format of the BoM, even though it is from the same customer, can change from one transmission to the next, making it difficult to match and confirm data. Even language can vary from BoM to BoM.

Correctness
Incorrect data is a serious problem. Common errors include invalid manufacturer or supplier information, obsolete data and incorrect part numbers (i.e., the MPN given does not match the description of the part, or the MPN is not recognized by the manufacturer/supplier). Again, AMLs seem to be the predominant problem. Additional errors can result from receipt of information in hard copy format, which requires manual data entry, an error-prone and time-consuming task.

Defect levels — anecdotal data
The NEMI team gathered anecdotal information from several OEMs and EMS providers, and discovered that companies consistently cited errors and lack of a standard format as leading causes of problems when working with BoMs. Estimates of error rates and of the time required to resolve data problems were also similar from company to company.

One leading EMS provider reports that, in the first two to three months of engagement with a new customer, an average of 80% of the BoMs received contain errors that must be resolved with the OEM. Of the component information received, 40% of the parts are found to have errors that require correction by the OEM. These errors include inconsistent content, invalid manufacturer or supplier information, incomplete or truncated information, missing information, obsolete data, and customer-specific information that requires the customer to send a letter of authorization before the supplier will release information to the EMS.

The same EMS also says that, of the 40% defects at the parts level, 20% of the defective data (or 8% of the entire BoM) is due to parts on allocation to the customer or parts that have become obsolete. Obsolete parts typically have a replacement; however, the EMS cannot procure new parts until confirming the change with the customer. It is possible, for example, that the OEM may have a lifetime buy on the old part because the new version will not work in a particular application. Figure 2 shows the defect levels — by process step — experienced by this EMS according to process steps.

Although this EMS provider's estimate of an 80% error rate for neutralizing and validating BoMs received from customers is surprisingly high it, unfortunately, does not appear to be unique, based on information received from other EMS providers. Data collected by a second EMS (*see Table 1*) corroborates and quantifies the problems identified by the first EMS. In particular, their data highlights the pervasiveness of incomplete and missing information.

A leading OEM that works closely with its EMS providers to resolve data issues told us:

> *Ability to start up new products rapidly is impacted by the quality of our documentation. Thirty-five percent of the component data have problems. If we do not have a process in place that will check and correct the errors in the audit report prior to sending the AVL to the EMS, these errors will continue to occur.*

The document control group of another major EMS provider had this to say:

> *I agree with the estimate that 80% of the BoMs I get have some kind of a problem. They are almost always incomplete in terms of what we need to estimate product cost. We usually end up asking more questions of the customer, searching through all the other assembly files we receive with the quote package, or making an educated guess at the missing information. Some items that almost always need attention are:*
> - *Assigning schematic reference numbers to hardware.*
> - *Reconciling hardware requirements between the BoM and what's actually required.*
> - *Removing items that should not be part of the BoM (such as specifications, drawings, etc.).*
> - *Structuring programmed devices in a parent/child relationship (so that, for example, a blank part and the software needed to program that part are differentiated).*

COST TO INDUSTRY

Despite the pervasiveness of the problem and the magnitude of its impact, the issues associated with BoMs do not have a high level of visibility among senior managers in OEM and EMS provider organizations. Time and energy are spent on dealing with the immediate day-to-day issues and "fire-fighting," while little or no time is spent addressing the root of the problem. The perception is that, as long as the EMS has received data, the situation is manageable. Little thought is given to whether the data sent is error-free, how much time is required to "clean" the data, and what the impact on cycle time is. The reality is that more resources are devoted to correcting data than to correcting the problems that cause bad data in the first place — i.e., to make sure that the data is clean and consistent before it is passed to a partner. The industry's design, PDM and ERP tools are all creating different file formats. Time and energy must be spent on developing format translators, or data neutralizers, before the data can be evaluated for accuracy and consistency. Currently, none of the leading PDM or ERP systems includes tools to validate data for accuracy and completeness.

The time lost in dealing with data issues can greatly impact the ability of the EMS to deliver products to its OEM customers on schedule. Each defective part adds an estimated 40 minutes to the processing time of the BoM, and the lag time is much longer. On average, delays can range from one day to several weeks, depending on the responsiveness of the information provider.

For example, if a BoM has 100 unique parts and 40 of the parts have issues, the processing time would increase by 26 hours or approximately 3.5 working days (assuming the EMS and OEM resolve the discrepancies right away). If the queue/wait time required for resolving issues is added to the calculation, the overall cycle time can increase by weeks.

One leading EMS provider estimates that it takes 10 minutes of engineering time to analyze each error and recommend a correction to the OEM. When the volume of parts produced and defect rate are factored in, the time spent on correcting errors becomes significant. For example, 10,000 parts (which is what a leading EMS typically sets up on a quarterly basis) with a 40% defect rate would require 40,000 minutes (66 hours) of engineering time. In addition, there is time spent tracking each issue, reporting back to the OEM, following up and, finally, entering the correction into the systems.

Another EMS reports receiving a 75-line-item BoM with 40 errors. It took two days of cycle time to prepare the product for manufacturing. Yet another EMS provider estimates that, given the volume of BoMs and new parts going through their system, they are losing six person-months *each month* to finding, reporting and correcting data errors and inconsistencies.

The greatest cost, which is difficult to quantify, is how lost time impacts time to volume and time to market. Until the last issue on a BoM has been rectified, the product build cannot be completed and, in many cases, the manufacturing process cannot even begin.

CREATING THE "PERFECT BOM"

The NEMI team is recommending that industry develop, define and strive to attain a "Perfect BoM." This BoM will not only contain data that is consistent, correct and complete, but it will be communicated among data systems and manufacturing partners in a clear, unambiguous manner.

The Perfect BoM should provide all of the information needed to describe the product and enable EMS providers and suppliers to proceed with purchasing, manufacturing, etc. with minimal back-and-forth between partners. Key to achieving these goals is implementation of a standard data format.

Today, there is no agreed-upon set of BoM characteristics or fields, and there is no universally recognized format for structuring BoM data. By standardizing on what is included in the BoM (data content) and how the data is formatted, OEMs and EMS providers can significantly reduce the errors and inconsistencies that currently erode efficiency and time to market. A major advantage of adhering to standardized format and content is that it makes standard tools possible. Today, EMS providers have their own sets of tools to deal with the different data formats they receive from customers. If all BoMs provide the same information using the same data format, solution providers can develop tools to translate the data into the EMS providers' systems. Such tools will allow EMS providers to stop wasting time interpreting content and format, and go straight into execution, and that means improved time to market and time to volume for their OEM customers.

Standards-based data structures already exist that can serve as the data exchange mechanism for the Perfect BoM. The IPC Product Data eXchange (PDX) standards, originally developed by NEMI's Virtual Factory Information Interchange Project (VFIIP) and published by IPC in the fall of 2001, provide for a standardized BoM format and file type. The PDX standards suite is described below. Specifications for all of the PDX standards are available at webstds.ipc.org

IPC-2571 Generic Requirements for Supply Chain Communication
This sectional standard provides an "overview" of the entire suite of standards for supply chain communications and describes how PDX is expected to work in conjunction with other related standards and formats.

IPC-2576 Requirements for Supply Chain Communication of As-Built Product Data
This sectional standard defines how manufacturing product genealogy information — the build history of boards and final assembly — is exchanged. All characteristics of the product are represented as well as its serialization, lot information and how it was manufactured. This information may be used to support products through the life of the equipment.

IPC-2578 Requirements for Product Design Configuration
This sectional standard facilitates quote, simulate, manufacture, configure, test and kit interactions among supply chain partners. It defines an XML encoding scheme, which enables a total product definition to be encoded at a level appropriate to facilitate supply chain interactions. An encoding scheme is defined for the BoM, approved manufacturers list (AML), approved vendors list (AVL), changes (engineering, manufacturing, product), and references to documents describing geometric and other part characteristics.

IPC-2577 Supply Chain Communication of Manufacturing Quality Assessment
This fourth PDX standard is currently a working draft. It provides an XML encoding schema to allow electronics manufacturing supply chain partners to exchange as-built quality assessment and manufacturing process yield information. The information represented by this standard may be used to improve manufacturing processes and design criteria to incorporate design for excellence principles. The information represented in this standard includes: board fabrication characteristics related to form, fit and function; serialization; batch/lot information; manufacturing site; manufacturing date; part number; component and sub-assembly data.

The PDX standards were developed through a partnership between NEMI and IPC. In addition, RosettaNet, an industry consortium focused on development of open e-business process interfaces, worked with NEMI and IPC to integrate the PDX standards into its own Cluster 2 and Cluster 7 Partner Interface Processes® (PIPs®). These PIPs relate to distribution and update of production information and to the exchange of technical data for manufacturing. The three organizations coordinated closely to ensure consistency of naming conventions and structure between the IPC standards and RosettaNet dictionaries and specifications.

The PDX standards, coupled with the RosettaNet PIPs, give industry the ability to exchange information through a single port of the exchange software rather than requiring a different solution for each trading partner. As such, they are an excellent foundation for the Perfect BoM.

Elements of a perfect BoM
While data format and file type are defined by the PDX standards, there is still the need to standardize BoM content. Industry needs an agreed-upon set of BoM characteristics or fields. To be "perfect," the BoM should include everything that goes into the product, from raw materials such as wire, tape and solder paste, to the box that will be used to ship the product. It should make parent-child relationships clear, differentiating between components and materials that are part of a subassembly versus the overall assembly. For example, information about programmed parts is typically structured differently from BoM to BoM, and is often open to interpretation. The Perfect BoM should include blank parts as well as the software required to program the blanks, indicating the relationship between components and ensuring that all necessary parts and data are provided.

The NEMI Perfect BoM team developed a list of desired data to be contained in the Perfect BoM, identifying mandatory as well as optional characteristics. This list was then correlated to the contents of the PDX specifications. This list plus an excerpt of a PDX file are available in the Perfect BoM whitepaper on the NEMI website at:
http://www.nemi.org/newsroom/Articles/BoMwhitepaper.pdf

NEW TOOLS NEEDED
A standard exchange mechanism will provide a good start toward achieving the Perfect BoM, but it only addresses part of the problem. In addition, OEMs need tools that can catch conflicts between BoM data and engineering drawings and design files. They also need the ability to “pre-scrub” data and audit for a complete data package prior to transmission. Earlier identification — and correction — of errors will reduce the time required to resolve issues on the manufacturing end. Product data management (PDM) providers must work with OEMs to define user needs and determine how existing tools can be enhanced, or new tools developed, to check BoM integrity and validate data.

Up to 40 percent of line items have errors that occur when the EMS validates and sets up components. Problems typically encountered include: inconsistent content, invalid supplier information, incomplete information, missing information and customer-specific information (e.g., information on custom parts that are unique to a design company) Another 20 percent of line items have errors that occur in the sourcing of materials, such as problems with allocations (of scarce parts), suppliers withholding customer information (again, related to custom parts), and obsolete parts that can no longer be purchased through traditional channels.

Design process improvements can reduce BoM errors
As can be seen from the above discussion, many of the errors are introduced during the creation of the BoM. Therefore, if we want to have the most effective resolution of these issues, we need to work at improving the design process so that error rates are reduced or at least identified and resolved at an earlier stage. The following list provides some ideas of how these improvements can be made.

Integrity and consistency of data entry
Complete and accurate manufacturers' parts numbers (MPNs) are critical; therefore, product designers must be diligent in entering information. It is important to provide a correct description because most EMS providers use that description to populate key attributes in their PDM, ERP and manufacturing execution systems. Furthermore, the description must match the MPN, as the EMS often validates the MPN to the description. Standardizing on design tools and part number format across the entire company will help ensure data consistency.

Database consistency
Information flows to the EMS via several databases (e.g., component, design and ERP databases). Product designers need to ensure consistency within the design databases because this information feeds downstream databases. ERP and PDM systems should not be updated without going through the design database. It is also important to ensure consistency between the original MPN and the OEM's part number. EMS providers often see differences across design groups within the same OEM, where multiple part numbers are used for the same MPN.

Real-time updates
MPN changes need to be updated in real time. The next transmission of data from the OEM's design database to the EMS will overwrite the EMS provider's existing data. Late updates usually lead to high maintenance on EMS databases.

Design/manufacturing collaboration
The EMS typically tracks incoming defect levels. OEMs must work with their EMS providers to understand the issues relating to, and root causes of, defects and agree on action plans to solve the problems. It is also important to measure improvements. Most designers will collaborate on improving the design and direct cost, but are often "too busy" to collaborate on improving the data quality. EMS are typically very willing to collaborate with designers to improve data quality. Sometimes, an error is simply a misinterpretation of the data. A classic example is the MPN qualification status. Some manufacturers may be approved, but with certain restrictions (e.g., purchase only small quantities of a part). Collaboration and communication can help ensure correct understanding by the EMS.

MOVING FORWARD
The NEMI Perfect BoM team is continuing to identify issues relating to the bill of materials in the manufacturing process. We have outlined several activities on which we will focus our efforts in upcoming months. These include:

1. Validation of the use of the PDX format for the "Perfect BoM" through multilateral exchange demonstration efforts among companies.
2. Development of a standard specification for BoM content, to be submitted to IPC for formal standardization.
3. Work with PDM vendors to develop prototype solutions that incorporate the Perfect BoM in PDX format. Also work with vendors to develop data integrity checking tools.
4. Coordinate with OEM and EMS companies to beta test the PDM prototypes.
5. Produce and communicate industry-wide metrics as well as improvements over time.

Anyone interested in getting involved with the NEMI Perfect BoM efforts or in participating in pilot programs should contact Ken Chow at Celestica (416-448-4983, kchow@celestica.com) or Steve Christensen at Nortel Networks (770-708-7921, schriste@nortelnetworks.com)

GLOSSARY OF TERMS

AML Approved Manufacturers List – a list of manufacturers and MPNs that are acceptable/ preferred/disqualified for use as a given OEM part number.

ANSI American National Standards Institute - mission is to enhance global competitiveness of U.S. business and quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems – www.ansi.org

AVL Approved Vendors List – similar to, sometimes used interchangeably with, AML; usually focuses on where a part is purchased rather than who manufacturers the part.

ASL Approved Suppliers List – similar to AVL.

BoM Bill of Materials – list of components required to build a given product.

CAD Computer-Aided Design – software used to design an electronic or mechanical product.

EDI Electronic Data Interchange – industry standard for exchanging manufacturing procurement data electronically.

EMS Electronics Manufacturing Services – a company specializing in manufacturing electronic products for other companies.

ERP Enterprise Resource Planning – software that plans use of material, labor, financial resources, etc.

FIS Factory Information Systems – software that tracks/records status of manufacturing work in progress.

IPC Association Connecting Electronics Industries – an industry association of designers, printed circuit board manufacturers, electronics assembly companies, suppliers and original equipment manufacturers - www.ipc.org

MES Manufacturing Execution System - software system that manages data, steps and processes for manufacturing products.

MPN Manufacturer's Part Number – part number assigned to a product by component manufacturer; used to procure components.

NEMI National Electronics Manufacturing Initiative - an industry-led consortium focused on facilitate leadership of the North American electronics manufacturing supply chain – www.nemi.org

NPI New Product Introduction – process of bringing new product to market.

OAGIS Open Applications Group Interface Specification – www.openapplications.org

OEM Original Equipment Manufacturer

PDM Product Data Management – software to track all aspects of product data.

PDX Product Data eXchange standards – IPC standards that utilize an XML encoding scheme to enable supply chain partners to exchange product content, changes and subsequent manufacturing information in a common language – webstds.ipc.org.

PIP™ Partner Interface Process™ (PIPs™), developed by RosettaNet to define business processes between trading partners.

RosettaNet – a consortium of computer makers, reseller, and users creating e-commerce standards for transaction-centered data exchanges using a standardized set of terms for product, partner and transaction properties - www.rosettanet.org.

TIG Technology Integration Group – all NEMI projects are organized under one of five TIGs (Board Assembly, Environmentally Sustainable Electronics, Factory Information Systems, Optoelectronics, Substrates)

VFIIP Virtual Factory Information Interchange Project – a NEMI project focused on developing a set of XML-based standards that will shorten the time and reduce the cost required to establish and maintain information exchange partnerships across the manufacturing supply web.

XML eXtensible Markup Language – the universal format for structured documents and data on the Web – www.xml.org or www.w3c.org.

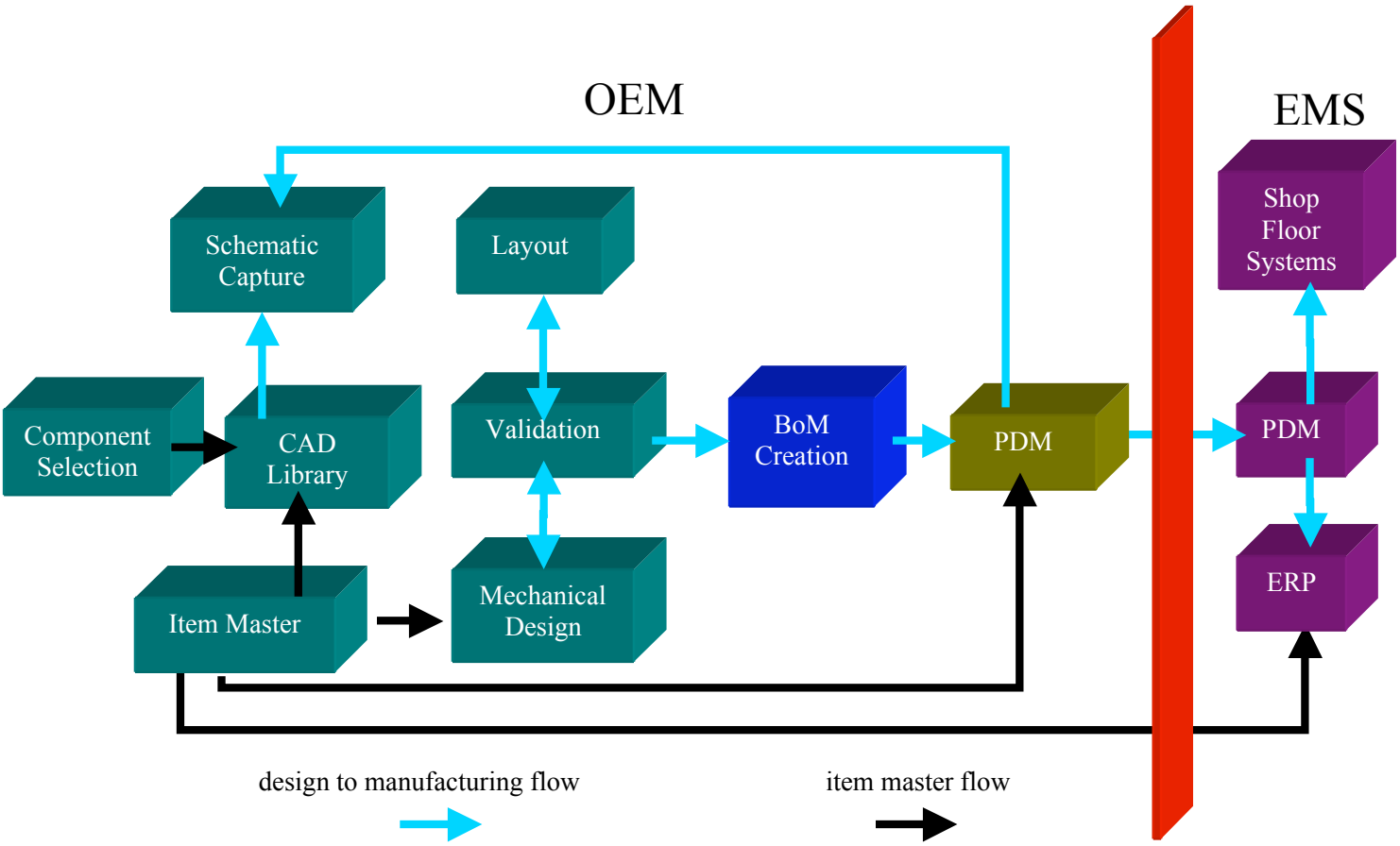

Figure 1. This diagram represents the flow of information between OEM and EMS provider, from design through manufacturing.

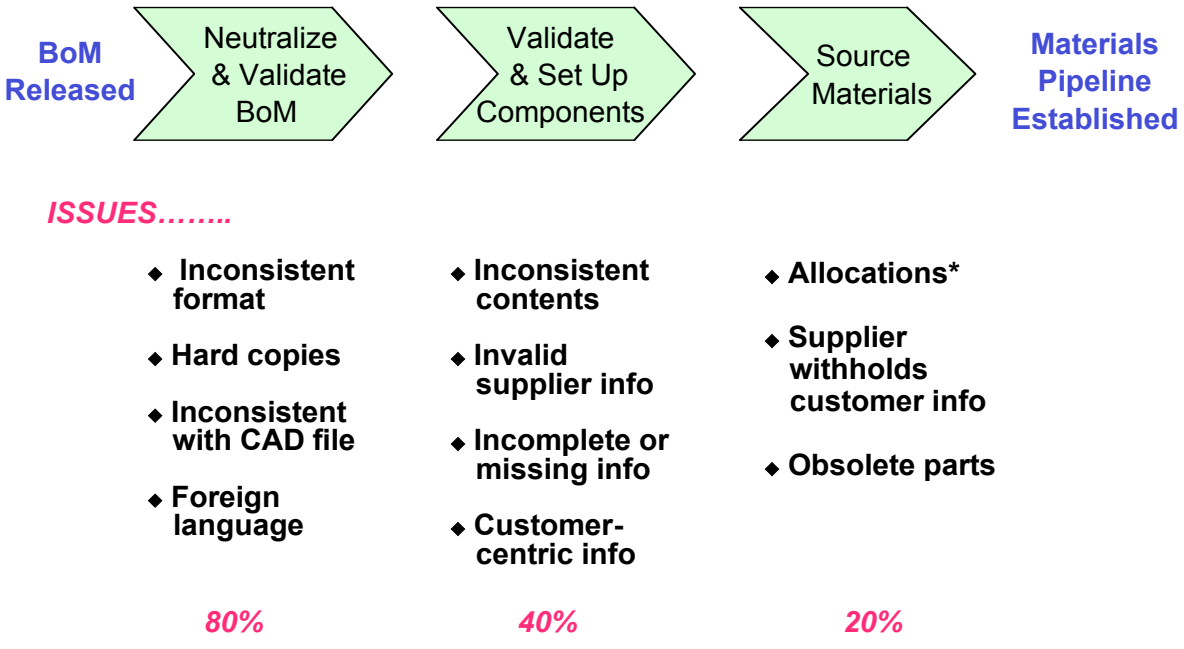

Figure 2. This chart indicates defect levels experience by an EMS provider at various steps in the BoM data set-up process..

	Neutralize & Validate BoM				Validate & Set up Components			
	(Yes / No)				(# / total)			
Customer	**Inconsistent Format**	**Hard Copies**	**Inconsistent with CAD File**	**Foreign Language**	**Inconsistent Contents**	**Invalid Supplier Info**	**Incomplete Info**	**Missing Info**
Customer A	NO	NO	NO	NO	0/6	N/A	0/6	0/6
Customer B	YES	NO	NO	NO	0/1	0/1	0/1	1/1
Customer C	YES	NO	NO	NO	0/40	N/A	10/40	10/40
Customer D	NO	NO	NO	NO	0/6	N/A	6/6	6/6
Customer E	NO	YES	NO	NO	0/1	N/A	0/1	0/1
Customer F	YES	NO	YES	NO	0/30	25/30	25/30	25/30
Customer G	YES	NO	YES	NO	20/200	N/A	100/200	10/200
Customer H	YES	NO	NO	NO	0/200	50/200	150/200	10/200
Customer I	YES	YES	NO	NO	2/5	5/5	1/5	1/5
Customer J	NO	NO	YES	NO	0/10	N/A	0/10	0/10
Customer K	YES	NO	NO	NO	25/80	N/A	60/80	60/80
Customer L	NO	NO	YES	NO	0/30	N/A	2/30	2/30
Customer M	NO	NO	NO	NO	N/A	N/A	N/A	N/A
Customer N	NO	NO	YES	NO	0/8	N/A	1/8	1/8
Customer O	NO	NO	NO	NO	0/8	0/8	2/8	2/8
Customer P	NO	NO	NO	NO	N/A	N/A	N/A	N/A

Table 1. Defect data collected by a major EMS provider.