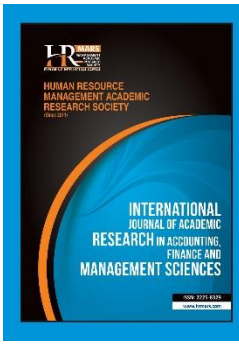

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ISSN: 2225-8329

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To Link this Article: http://dx.doi.org/10.6007/IJARAFMS/v2-i1/9872 DOI:10.6007/IJARAFMS /v2-i1/9872

Received: *14* January *2012, **Revised:** 19* February 2012*, **Accepted:** 06* March 2012

Published Online: 28 March 2012

In-Text Citation: (Chen et al., 2012)

To Cite this Article: Chen, H.-C., Lu, M.-J., Liu, C.-C., & Tsai, C.-H. (2012). A Study of the Performance Improvement of Bill of Material Document Sign Flow System. *International Journal of Academic Research in Accounting Finance and Management Sciences*, *2*(1), 79–96.

Vol. 2, No. 1, 2012, Pg. 79 - 96

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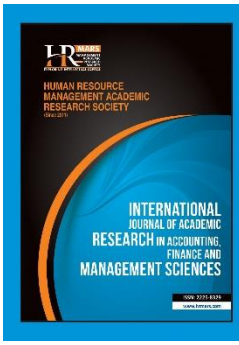
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A Study of the Performance Improvement of Bill of Material Document Sign Flow System

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Abstract
Due to information and network communication technology have a great improvement; electronic management flow system already can be easily implemented. It operates sufficiently with members in-groups and enhances total operational efficiency, flexibility, lean and agility of enterprise. Electronic management flow system has some important properties: information transfer, automatic flow and operation management and control. Those properties can help company to reduce cost, shorten lead time, increase productivity, and achieve a good total quality management (TQM). In the same time, it also can help company to create business competitive advantage. This study focused on the performance improvement of bill of material (BOM) documentation sign flow in A-company. To enhance efficiency and effectiveness of BOM documentation sign flow, A-company passes through information department to integrate relative documents sign of other departments to make an electronic sign program to achieve cost reduction and speed-up efficiency of BOM document sign since 2005. This case uses BOM document release to study the benefits of electronic documentation sign in product engineering department.
Keywords: Electronic Flow Management System, Electronic Sign Program, Bill of Material.

Introduction

Innovation is the important issue in the 21st century and innovative management becomes necessary for sustainable development. In order to pursue economic development and competitiveness, companies should value their innovative management and fulfill the goal of sustainable operation by effective innovative management (Tien *et al.*, 2007; Liu and Tsai, 2009; Chung *et al*., 2010; Wu *et al*., 2011). In order for the enterprise to improve the competitiveness, it should devote to the establishment of the good information system. On the definition of the e-enterprises, different scholars propose different views. Basically the so called e-enterprise is according to the electronics, which outside of the enterprise cooperates with its interior function flow; for example, the Enterprise Resource Planning (ERP), Customer Relationships Management (CRM), Supply Chain Management (SCM), e-business, and along with the Business Process Reengineering (BPR). The business flow is behind these information systems, so we can use management system to construct an automatic, changeable work process through the fast developing administrative environment. Traditional paperwork not only consumes massive manpower, space and time, also it is not effective on tracking work documents. Also storing the processed documents will occupy too much space, making it impractical for enterprises to search for more space and to save them continuously. In addition to the increasing knowledge on recycling, cutting down on the use of papers also protects our environment. In the past, using manpower is the only way to complete any types of administrative jobs. In every step, at least one person has to enforce or verify the work documents, and then the documents are sent, through manpower, to the next person/station. Because the documents have to go through every approval from all of the relative departments, they not only waste time and human resources, but this process is also often delayed by the overstocking of documents and the carelessness of the employees. Therefore, it is desired to use the way of approving electronically to solve this problem.

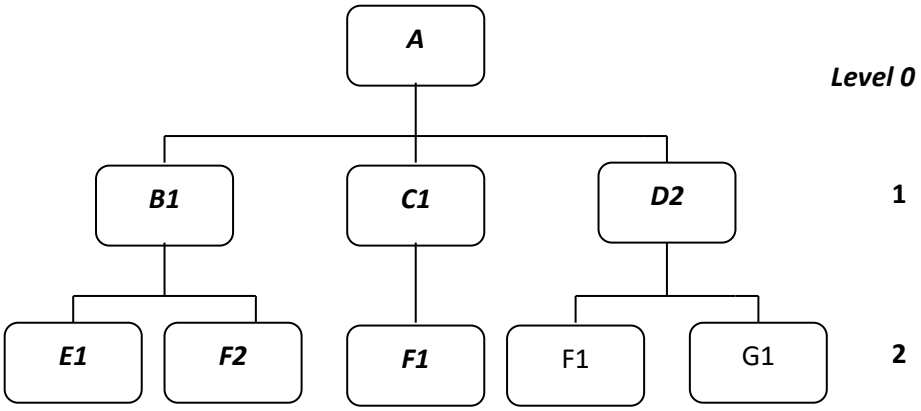
This study will discuss about the difference and efficiency of electronics processing of the Electronics Signature Program (ESP) comparing with the traditional paper works. Due to the internet, people can utilize work software to substitute traditional paper works. The advance database system also provides us with stable and high capacity of information storing environment. The computers efficiently help us to design flow program. It also controls, monitors, and calculates the process of work flow. By using the flexible document flow to set and finish tracking and administrating, the processing time of documents is greatly shortened. It enables employees to check the status of document delay, to increase the efficiency of document processing, to simplify the administration of files management, and to provide the function of quick search. For example, even if the staffs are absent, they still can read the document through internet and approve it. Because of the help from the Electronics Flow Management System, employees can finish the signature approval via different times and locations. It has shortened the traditional process into a “One-click-away Distance”. Thus, the managers of business enterprises can easily observe the behavior and efficiency of the workgroup.

Literature Review

This study has focused on researching on Final BOM Release improvement and literatures that are related to BOM. The reviews are described as follows:

The Definition and Structure of the Bill of Material (BOM)

The Bill of Material (BOM) is a detailed account used for defining, recording, and saving the final product and its make-up, contents, quantities, and structure. In the definition of the BOM, the final product and its structure are related as: the final product can either be the finished goods or the semi-finished goods; however, the structure is indicated as the semi-finished goods or its components. The contents in the BOM include (Kinney, 1990; Tsai, 1996): (1) Parent and child's identification number and other relations; (2) the quantity of the "child" while the product is assembling; (3) "Child's" effective date and expiration date; (4) Inventory of components, price and manufacturing, and packaging process data, etc. The American Production and Inventory Control Society (APICS) defined BOM as: A listing of all the subassemblies intermediates, parts, and raw materials that go into a parent assemble showing the quantity of each required to make an assemble. It is used in conjunction with the master production schedule to determine the items for which purchase requisitions and production orders must be released. Further more, the BOM provides us with a menu of components, materials, and instructions. In this way, the BOM can also be called as Product Structure or Material List. The BOM is usually presented in a Level-by-Level way: Level 0 represents the finished products, Level 1 as structural components, Level 2 as the composition of the structure in Level 1, and so on as Level 3… until the list reaches the most basic components/raw materials. The tree structure of BOM is illustrated as in Figure 1.



Note: Finished Product: A; Subassembly: B, C, D; Parts: E, F, G

Figure 1. Tree structure (BOM) of product A

The BOM structure can be presented in many different ways, such as Explosion and Implosion (Liang, 1998; Mather, 1987; Tsai, 1996). This study briefly describes the different BOM structures as followings:

(1) Single-Level Explosion

The Single-Level BOM has the most basic list of different types of materials. It only specifies the relationship between the assembling work and its components as presented in Figure 2. The Single-Level BOM includes the list of the final products and its components, and information on each of the

parts, such as: (1) the component unique ID number (serial number); (2) brief description of the components; (3) the quantity of components needed to make the final product; (4) the measure unit.

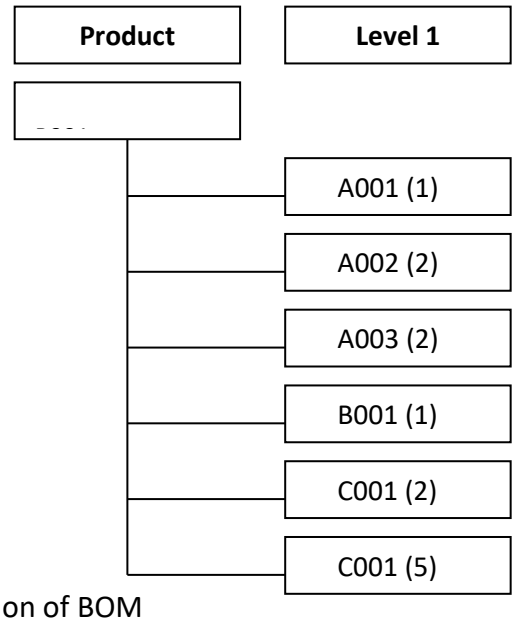


Figure 2. Single-Level Explosion of BOM

(2) Indented Explosion

This type of explosion lists the relationships between all the components at every levels of assembling work. It includes the amount of components an assembling work needs, and its explosions have the like of different levels and zigzag shapes. Because the finished product or the sub-product uses the way of explosion starting from the top level all the way to the bottom level, if another sub-product is seen in the explosion, again use the way of starting from the top level down to the bottom level for the level below the sub-product until all the components have their explosion. Therefore, Figure 3 helps to make further understanding of the make up and structure of the indented explosion.

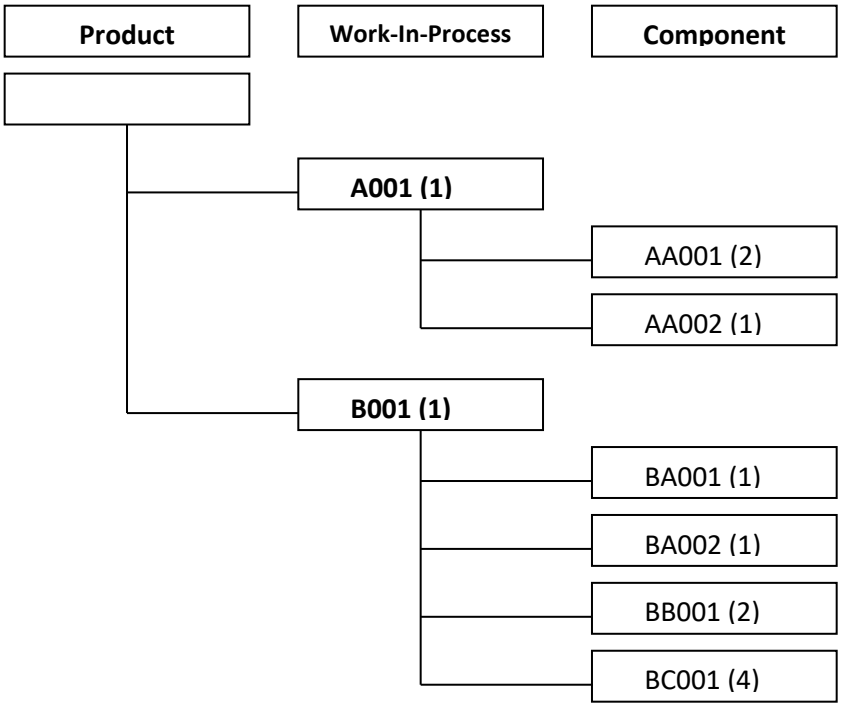


Figure 3. Indented Explosion of BOM

(3) Summarized Explosion

This type of BOM lists all the materials and quantity of every level for making the product. It only presented the total quantities of materials of different level, but it does not sure the relationships of different levels. In this way, we cannot see the procedures for assembling the product. As shown in Figure 4, this kind of BOM is convenient for inspecting the quantity of materials used and the change of the components' cost for the product.

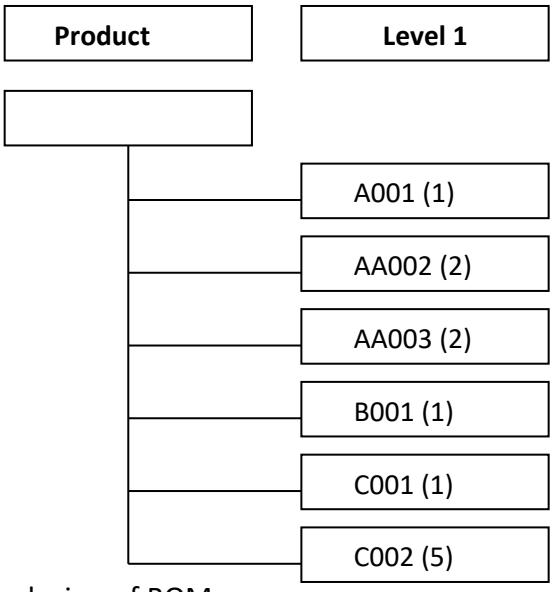


Figure 4. Summarized Explosion of BOM

(4) Single-level Implosion

The Pegging List is a list that records each component with the product or sub-product that it is used in. The Single-Level Implosion lists the relation with the assembling work with its component as presented in Figure 5. The Single-level Implosion is presented in the opposite way as the explosion because it starts from the bottom level and ends at the top level. Through this implosion, one can clearly know which component is part of which product or sub-product. When there is a change in the component or product structure, one can immediately know which component is affected by this change.

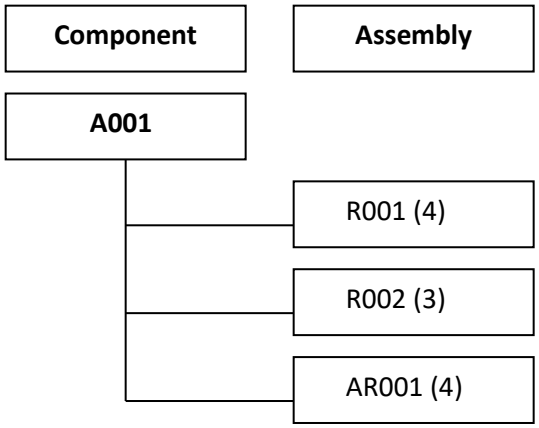


Figure 5. Single-level Implosion of BOM

(5) Indented Implosion

This type of implosion is composed components that help to find the BOM's original item. It is expanded from the bottom to top level. When we discuss about the original components, we can keep expanding the list until the BOM reaches its final product. The implosion has different layers or indented style, so we can clearly see the relationship of the original part and its components. In this way, this type of BOM can effectively respond to the changes of the design of the product and its influence (See Figure 6).

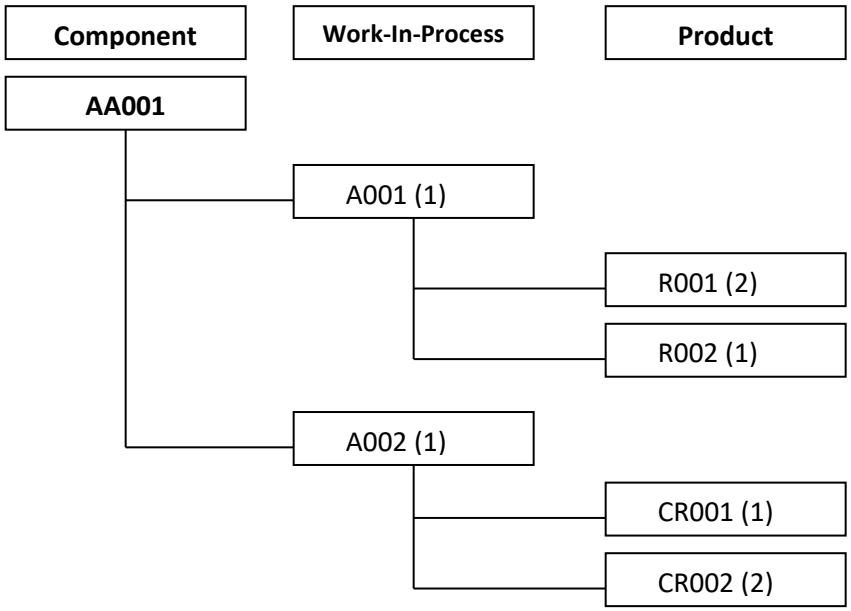


Figure 6. Indented Implosion of BOM

(6) Summarized Implosion

The Summarized Implosion is using the sub-product or the component that starts from the bottom level and goes up to find its original component until it reaches the final product. No matter if this component is an original component or a sub-assembly; it will add up the total quantity of all the components in every level and presents them as shown in Figure 7. This type of BOM can immediately detect any amount of components that can affect the production quantity of the final product or sub-product.

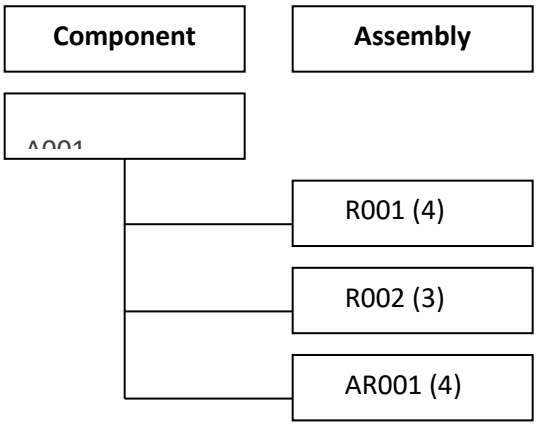


Figure 7. Summarized Implosion of BOM

Different Types of BOM

There are different types and structures of BOM for different kind of departments and environment. We can briefly introduce to each type of the BOMs as the followings:

A. Engineering BOM (EBOM)

EBOM is specially used for product designing department. This type of EBOM show the basic structure for the product, which can use to express the functions and design that made from engineers. In the product management system, the EBOM is mainly focused on the basic materials to categorize different products. It can also be used as a management of the different product designs (Liang, 1998; Tsai, 1996).

B. Manufacturing BOM (MBOM)

The MBOM is used on the limit on manufacturing of product and its materials. It is related to calculations of the BOM, and it also shows the actual need of materials. The MBOM is presented in three different levels: level 0 is the final product; level 1 is the assembling group; and level 2 is the components for the product (Huang, 1999; Tsai, 1996).

C. Modular BOM

When a product's type is given selectivity, the different types of components are being classified into different modules. The different types of products are then made from these modules. When the components become modular, the list it produces is called the Modular BOM.

D. Pseudo BOM

When applying Modular BOM, many materials will become the final product. In the Material Requirements Planning (MRP), every final product will all need to be analyzed and to plan MPS. In order to prevent the difficulties caused from modulating, it is important to apply the Pseudo BOM (Liang, 2000; Tsai, 1996).

BOM and Its Relationship with the Manufacturing System Department

There are five main factors that composed of a good system: 5 M represents Materials, Machines, Man, Method, and Money. The 5 M led to the development of different departments, such as inventory management, production management, manufacturing, procurement, quality management, financial, and other departments. From Figure 8, we can see the different interrelationships between different departments, and every department get their information from BOM. In this way, BOM is not just reference information, for it is very important information affecting the whole process of producing and designing of a product.

The BOM and its interactions with the functional departments are described as the followings (Mather, 1987; Rusk, 1990; Tsai, 1996):

(1) BOM and Design Department

The product design can be changed sometimes for different needs, so it is very important to keep the information of BOM as new, up to date, and accurate as possible. When the design department develops new products, it needs to present every new material, information, and components that are used to make the product in a structural tree way into the new BOM. Also, according to the new BOM, every component including the information of the new product should be placed under the database.

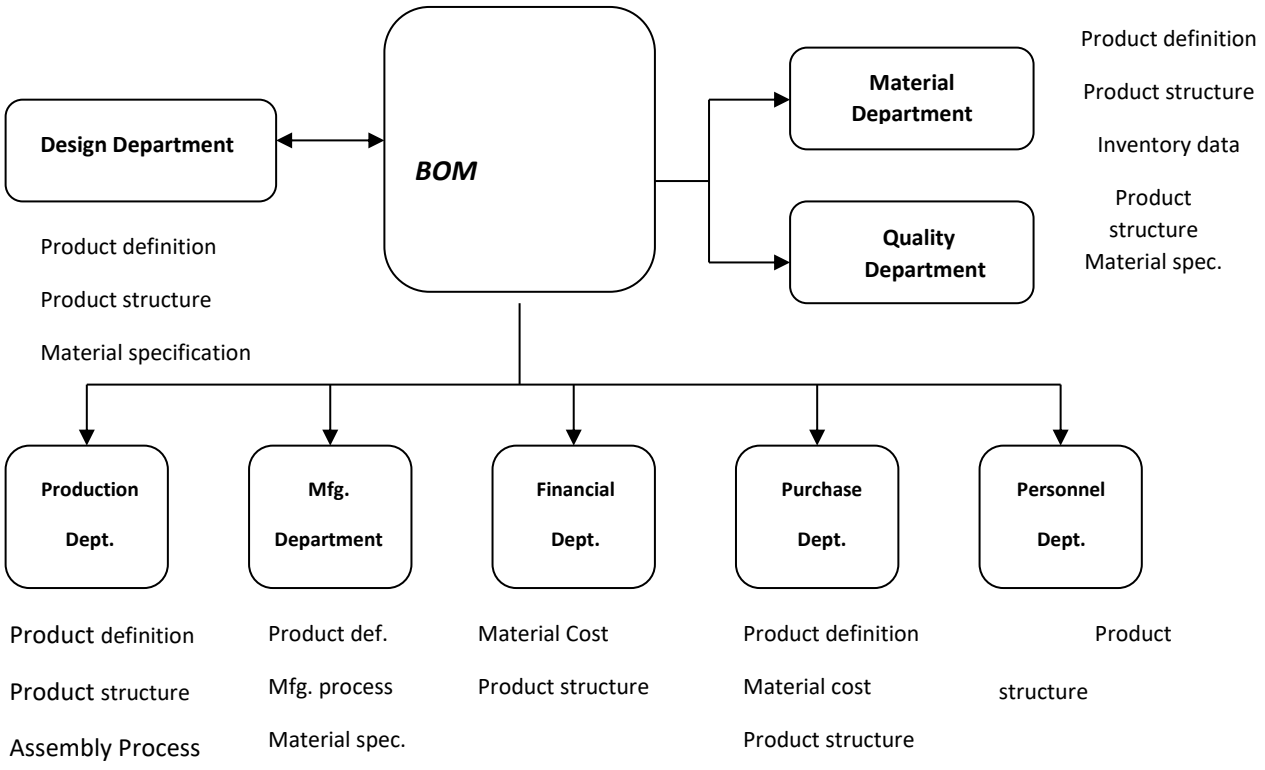


Figure 8. BOM and its relationships with the functional departments

(2) BOM and the Production Management Department

When the factory has received the order forms, the production management department will arrange a Master Production Schedule (MPS) according to the order forms' due-dates. The BOM structure explosion and the stored information of components then can arrange the final product and its structure from the top level to the bottom according to the MPS. This can also help to control the production process of every group of components and to ultimately meet with the shipping due-date.

(3) BOM and Inventory Management Department

The inventory management department is responsible in preparing, storing, and managing different materials. When the production management department sets the main manufacturing plan, the inventory management department then follows the information from the BOM and ordering different quantities of materials (Net Requirement). Finally, the inventory management department processes the prepared components and assigned different jobs. In this way, the inventory management department makes sure that there are enough supplies to keep the production running.

(4) BOM and the Purchase Department

The goal for the purchase department is to buy quality materials from the supplier for the least and most reasonable price. Having a good purchase system not only reduces the complexity of the

purchasing process, but it can also decrease the chance of unnecessary lost of purchase cost. For the purchase department, the control of time is its main problem, and BOM is the key to solve this problem. Through the information of BOM, the purchase department then is able to correctly purchase sufficient amount of materials and preventing too much storage or too less storage.

(5) BOM and Manufacturing Department

The BOM provides the right information of assembling for different departments, and it eliminates a lot of problems that might occur during the production. In this way, the BOM improves the quality of products. In the control managing system, the BOM not only includes the structures of the product, it also shows the routing information which can put together the BOMfr (BOM of Manufacture) (Hasting and Yeh, 1992). Then the BOM can work more closely with the Manufacturing Department.

(6) BOM and the Quality Management Department *(Chien et al., 1999)*

The product's structural tree diagram from the BOM explosion and every component's design information have helped the quality management department to perceive the qualities of every production and assembling process and also help to see the controlling and tracking of product formats which the employees of the department are assigned to do.

(7) BOM and Human Resource Department

For the human resource department, it can understand the need of any human in the production process due to the BOM. The human resource department can also adjust and plan the human resources ahead of the time, and it can fully use the manpower throughout the manufacturing process.

(8) BOM and Financial Department

According to the financial department, through the BOM one can clearly calculate the material and assembling cost for every production process, and careful planning of cost can prevent its unnecessary use.

BOM and Reference Studies

Hastings and Yeh (1992) thought that in the controlling system of computerized manufacturing and inventory, the two most important documents of the database storing are the BOM and Routing. Now the system mostly divides the two into different subdivisions. The combination of BOM and Routing was called the BOM of Manufacture (BOMfr). The BOM of Manufacture focuses mainly on the importance of production line, and it is very useful on the aspects of production control, material flow, and price estimation. There are three benefits of BOMfr: (1) Various controls over a product; (2) Controlling of a great amount of materials; (3) Material specific operation manifestly. This operation contains the items of the next level. If a material is the intermediate product, then it will have its own BOMfr.

Under the environment of demanding consumers, products increase their variability. How to organize this product information is a major problem that resulted from the variability. Therefore, Olsen and Saetre (1998) developed a Generic BOM system; it created a standardized model to describe the final product and the differentiated values, and it prevents the creation of information

redundancy that resulted from product differentiation. Shiah (2000) use the informational databank developmental BOM system to define and describe the final product, sub-product, and the structure and related information of the assembling component. It also provides product design, process planning, production, etc., all of which are information that are necessary for the system. Chang *et al.* (1997) suggested a three level M_BOM plan to solve the conflicting problems between E_BOM and M_BOM. The first level of the plan is the primary constructing structure of M_BOM; the second level is improving the M_BOM structure; the third level is adjusting the M_BOM structure.

Wacker and Miller (2000) believe that under the environment of the "Configuration to Order" (CTO), it is necessary to use the Planning Bills of Material. The goal is to simplify complex product structure and solve problems concerning product variability. This is why the author suggests using the theory of Planning BOM. Through the theory of Planning BOM, designing new products can improve the quality of the products. Chung (2000) suggested a model for organizing product information used for assigning production. It can effectively plan and control consumer orders, product information model describing BOM, and creating two production information structure, and then it provides the production plan and control system's need for information. The expansion of organized production information will more effectively control particular consumer orders. Hsieh and Tsai (2001) suggest using BOM as a guide, class as an Automated Storage/Retrieval System (AS/RS) and "BOM-oriented class-based AS/RS Assignment Method" being used under the environment where CIM is set as the basis. This technique not only possesses the advantage of categorizing, it also effectively organizes AS/RS into the "Computer Integrated Manufacturing" (CIM) system. The manufacturing production system needs to be recorded in the material properties, and BOM is the most important source of information for material property. By using BOM as a main branch for the production system, then the CIM system is able to be thoroughly integrated.

Engineering Change (EC)

The main goal for the engineering change is to target on the products, the process of manufacturing component materials, and the assembling order in order to perform correction for changes. This makes the process of manufacturing more effective or it satisfies the needs of consumers. In order to maintain its competitiveness in the manufacturing factories, the engineering change increases production's unavoidable but necessary process, but too much of the engineering change will produce instability for schedule planning resulting a decrease of effectiveness on production. The cause for engineering change can be discussed in two ways; the first way is discussing about the internal cause such as main defects of products, safety issues, abilities of newly add products, and decrease in cost, all are reported by enterprise manufacturers. The second way is discussing about market competitors and consumer reactions and other related outside causes such as a client's special needs and market trends etc.

Research Methodology

Case Study Background Information

Using a single case of A-company as an example and because A-company has different production trends, the enterprise plan is divided into manufacture company one and two. When the development of a product goes into its final stage, the RD BOM and other responsible units need to be confirmed in order for the process to be Normal BOM. The Normal BOM needs to be signed so the relative department can use the given information to assign different factories. Also, the use of

electronic signature enables us to save much time and improve the efficiency for product manufacturing.

The Flow of Manual Signature

When BOM released, it describes and explains the job of different department, such as: (1) Product Engineer (PE) who make or modify the product BOM; (2) Component Engineer (CE) who verify the electronics modules that are used by the researcher; (3) Purchase Agent (PA) who purchase materials for making the products; (4) Hardware Research Department (H/W RD) which research and develop the function of the product; (5) Mechanical research Department (MEC RD) which design the structure of the product; (6) Industrial Engineer Research Department (ID RD) which design the packaging for the product; (7) Software Research Department which test and write programs for the product; (8) Technical Manual Writer Research Department which produce the menu and guides for the product; (9) Manufacturing Engineer (ME) who coordinate the production of the product; (10) Project Leader (PL); (11) Product Manager (PM) who manage the integration of the new product and manufacturing schedules. From now on after the Final BOM Release is signed by its administrators, then the BOM will become the Final BOM (see Figure 9). The processes are described as the followings:

1. Product engineer bases on the requirements of product manager transformed the RD BOM into Final BOM. From the BOM system, every level of product RD BOM is printed out chronologically and a Final BOM Release Check List is also added to it, and thus begins the approval process.

2. When the document is being transferred through every department to be approved, the staffs in the departments of purchase, component engineering, developing, structural design, package design, manual writing, product testing, and manufacturing engineer that are responsible to sign the documents must confirm every RD BOM is valid.

3. After the project leader approves the document, the product project manager makes a final confirm to check if the product satisfies every requirement that the consumer has requested. Then the product engineer can transform the RD BOM into Final BOM.

After each signer in every department has confirmed the validity of the document, it can then be transformed to become officially the Final BOM. If the signers site out a problem in the BOM, the product engineer will correct it and then start the approval process over. Solely depending on doing the approving and transferring process manually cause delay in time. For one BOM released, it usually takes 2 to 3 days to complete the approval process. This not only affects the effectiveness of work time for the person who suggests the release, it also greatly affects the time for purchasing materials. It may also delay the product's prescheduled production process that can directly alter the product due-date.

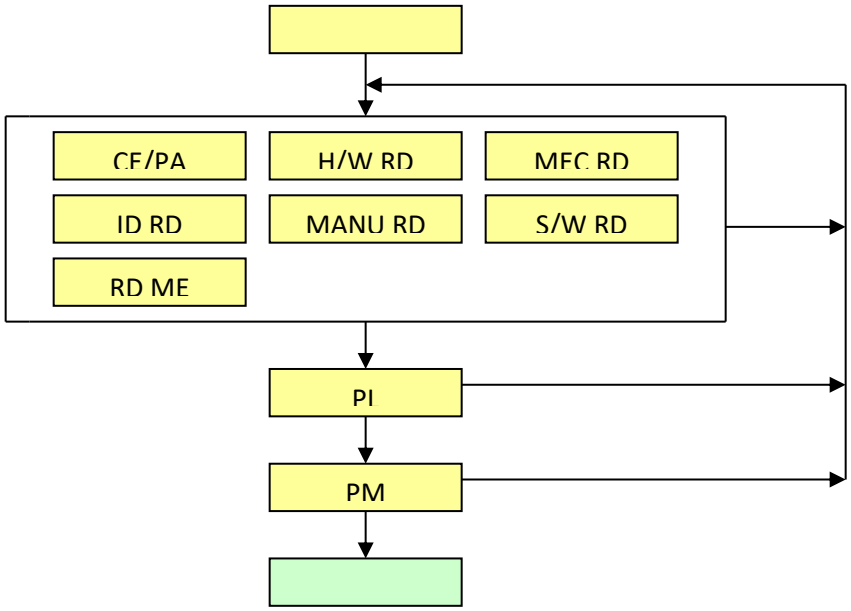


Figure 9. BOM Release traditional manual approval process

Implementing the Electronic Approval System

By applying the approval system electronically, it can mend the deficiencies of the original approval process and lessen the time for approval. With the help of the MIS department, the steps of the approval system created to be appropriate for the BOM Release are stated below:

1. Product engineers' base on the requirements requested by the product investigation managers has transformed the RD BOM into Final BOM. Using the BOM system to directly transform the RD BOM into a PDF file, the BOM Release system then can be used to apply by simply typing in the product number so the system can automatically provide with the product and client types and also the product names.

2. Every staff member who is involved in the approval process will be entered in the staff setup column. At this point of the process, the members of the purchasing and component engineering department are entered into the setup because they need to be the first to control information of due-dates and component substitution problems so they are the first ones to sign for approval.

3. Next in line to approve are the members from the departments of development, structure design, package design, manual writing, product testing, and programming. The signers of approval must confirm the validity of the RD BOM, and after every signer have approved the system will then move on to the next step for approval.

4. The members in the department of manufacturing engineer and the host of product planning will then to approve next. Finally after the approval of the product project manager, the Final BOM Release has been completed. The system will automatically transform RD BOM into Final BOM. It will also send out Release messages to inform other signers that the BOM Release process has been completed.

In the process of approving, once a problem has being discovered for the RD BOM, it is returned back to the original applier. When the product engineer has fixed the RD BOM, it is sent again to every department. This process will start off with the members of the purchase and component

engineer department again for their approval. This helps to prevent people not knowing which part of the document have been fixed.

Case Verification

Electronic Approval Process

Final BOM Release implements electronic approval process as shown in Figure 10; it will not need to use large amounts of paper to print out every step of the BOM for the signers to approve. It only needs to apply for a Final BOM Release Check List in the approval system. The check list has to be filled out with the product's related information, appointed signers, and the RD BOM e-information. The system will then sent the document to the next group of signers for their approval, and it also sends out notices for any signers who haven't approved yet to urge them to speed up the process. The applier is only necessary to look out for the document approval process and the condition of the document being rejected by any signers.

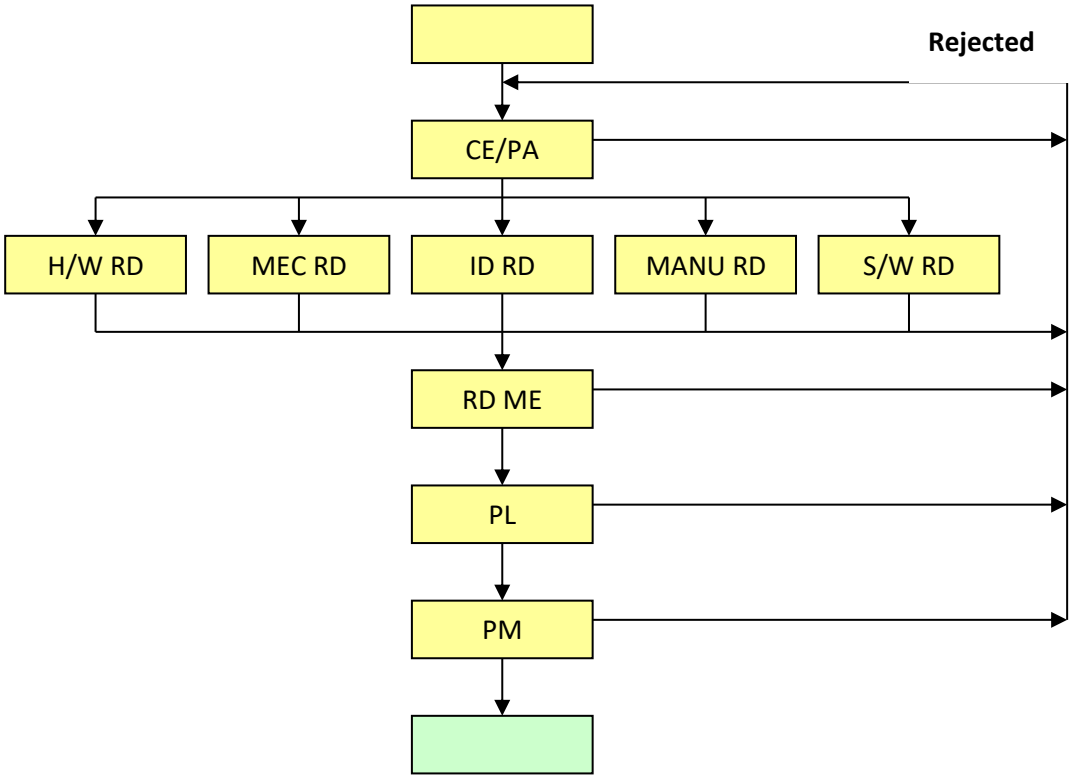


Figure 10. BOM Release Electronic Approval Process

The Results Analysis between Manual Approval Process and Electronic Approval Process

After implementing the electronic approval system, we analyzed the difference of time it takes the e-approval system to complete with the time it takes for the manual approval system. It was analyzed that the original manual approval system usually takes about 3 work days to complete (27 hours) as shown in Table 1. Part of the reason for the time it takes is because the purchase agent (PA) is situated at factory one, so it needs transportation time to send the documents back and forth. This is why the approval time is relatively increased.

Table 1. Total Time for Manual Signature

Department	Time before Improvement (Hours)	Location
CE	3	Factory two
PA	2	Factory one
H/W RD	7	Factory two
MEC RD	2	Factory two
ID RD	5	Factory two
MANU RD	1	Factory two
S/W RD	2	Factory two
RD ME	1	Factory two
PL	1	Factory two
PM	3	Factory two
Total	27 (3 work days)	

By using the electronic approval system, a systematic time schedule will keep the total time down to only 1.2 work days (11 hours) as shown in Table 2. The members in the purchase agent (PA) can directly approve on the system so it saved the extra time of sending the documents from factory one to factory two. After all the signers in the same level have finished approving the document, the electronic approval system then sends it to the next level of signers for their approval. This system shows that even though the purchase agent has finished approving first, it still have to wait until the component engineering department to finish their approval before the document can be sent to the development and design department. Therefore, as shown in Table 2, it takes only half of the original time to complete the whole process. Thus, it reached the effect of saving manual power and increasing its effectiveness.

Table 2. Total Time for Electronic Signature

Department	Time after Improvement (Hours)	Time Accumulation of Simultaneous Signature (Hours)
CE	**2.5**	**2.5**
PA	**0.5**	**2.5**
H/W RD	**6**	**6**
MEC RD	**1**	**6**
ID RD	**5**	**6**
MANU RD	**0.5**	**6**
S/W RD	**2**	**6**
RD ME	**1**	**1**
PL	**1**	**1**
PM	**0.5**	**0.5**
Total		11 (1.2 work days)

Conclusions

This study belongs to the company's individual case research. Bases on the company organization's characteristic, the research analyzes the electronic BOM Release document approval process and the increase in effectiveness and efficiency of working when electronic approval process is implemented with information technology. Approving documents will never use the traditional way of solely depending on manpower alone; it indeed has reached the effect of saving manpower and decreasing in paper usage, and it also greatly increased the effectiveness of working. One disadvantage of the electronic approval system is the immediacy of the signers taking actions of approval when received with the notice. This disadvantage influences on the process of being running smoothly and is a problem that deserves to have further discussion.

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