PDHonline Course G288 (3 PDH)

Bill of Materials Basics

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Bill of Materials Basics

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COURSE CONTENT

1. Introduction

I have worked in various manufacturing companies for the last 30 years. My responsibilities have included Engineering Analysis, Machine Design, and various Engineering and Production Management assignments. Along the way, I have been involved in several committees with a given objective to improve the efficiency between the principle groups of production. Maybe you have been involved in these as well. The committees would usually include representatives from each of the production departments like Engineering, Purchasing, Sales, and Manufacturing. They were intended to be multi-discipline. In the meetings, we would brainstorm over methods to reach the objective of better efficiency. As we met and dealt with the issues, it seemed our attention was drawn to the bill of material details and structure. Our conclusions were many times that the details of the bill of material had the ingredients for making the improvements in our operation.

Today's manufacturing environment has pushed us to search for ways to improve our efficiency and charter a path of continuous improvement. As the companies define their mission, the objectives filter through the organization and place demands on the various departments associated with production. The requirements for better efficiency becomes the charter for each of the departments who have a hand in developing, building, and shipping products. Better co-ordination across multi department functions is essential.

My experience with prior job assignments in Engineering management have demanded that I find ways to improve the coordination across departments and support the mission of better efficiency. I have concluded that much of the goal can be achieved by a strong focus on the bill of material and its many aspects. In this course, I present many of these aspects in detail. Although the samples used in this text may seem simplified, the methods and approaches can be applied to much more complicated assemblies and yield great benefits.

2. Understanding Your Company's Product Flow

To begin this class, I want to discuss a concept I call "Product Flow". In a manufacturing environment, we have a natural flow as products move through the company. Products, especially made to order products, typically move as follows, Sales (specifications) - Engineering (deliverables for manufacturing and purchasing are created) - Purchasing & Manufacturing - Manufacturing (fab, machining, and then assembly) – Quality (may or may not include a customer inspection) – Ship

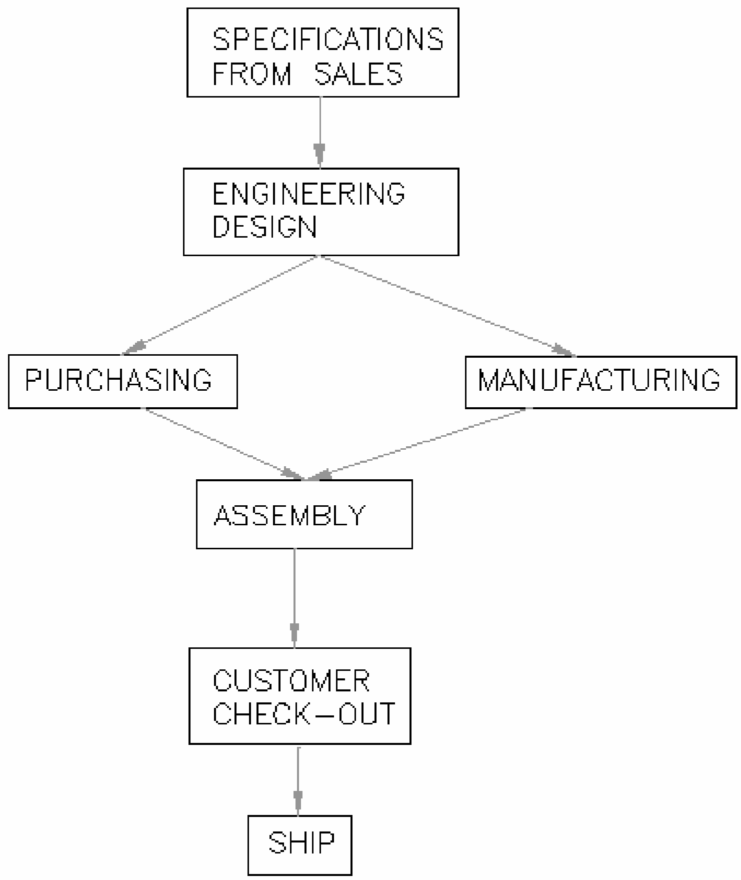

Figure 1 – Sample of a Basic Product Flow

This is called the "product flow". The flow may vary from company to company or product to product, but it does exist and is very repeatable within each situation. Figure 1 shows a very basic flow that needs be expanded to include more of the flow elements. Some additions may be special production functions and in stream inspections. If customer approvals exist, they would also be included. These approvals will show two lines of flow, where a non-approval will revert back to a previous block in the flow.

Mapping out the product flow is a great exercise to do across department functions. This exercise will facilitate cross departmental communication and will help everyone in the group get the big picture of the process. Developing the product flow for several products will show common trends and will identify the way documentation and material move through production. With all departments involved in the process, all the necessary detail will be reflected in the final chart.

If a survey was taken across all of the departments in the company and we asked, “What does Engineering supply in the product flow?” the answer would be what? …… Engineering produces the drawings. That’s what we’re most known for. What is never emphasized enough is the Bill of Material creation. In most organizations, the bill of material is released with the detailed Engineering. I know, historically this has been a debate, “who should create the bill?” As we go through this class, I think you will see the importance of having a detailed bill released to production under the responsibility of Engineering.

In the upcoming sections, we will show how the bill of material basic details is tied to the product flow. We will start out with some of the basic components of the bill and show how important it is to the product flow through the company. We will also go into detail to show how most, if not all, of the departments use the bill in one form or another.

3. Engineering Deliverables

As with many of the departments in our product flow, Engineering produces output for the product. I will refer to this output as the Engineering Deliverables. Let's discuss some of the typical deliverables from Engineering.

- Drawings – There are several types of drawings produced by Engineering. Some of the more common types are:
  - customer drawings (may or may not require customer approvals)
  - assembly drawings (sub assembly and final assembly)
  - details for piece parts (for the piece part manufacturing)
  - In some cases we have schematics for hydraulics, pneumatics, and electrical depending on what type of product it is that we are producing.

- Bill of Material (some type of bill is required at this point in the flow)

- Technical documentation (users or operation manuals for the customer)

As we focus on the importance of the bill, we need to view the deliverables a little differently. Although they are all very important, the bill should be regarded as the primary deliverable from Engineering. Drawings should be regarded as "visual aids" to the bill.

In a moment, we will start to develop a structured bill of material that will be very important to many aspects of the purchasing and manufacturing, and the overall product flow through the company. The drawings, which are obviously important, can then be linked to the bill at the level and point where they become necessary. We will show how drawings become the visual aids for that portion of the bill.

This idea of putting the bill first may be a departure from the way you think of Engineering. As we put the pieces together, you will start to see how and why everything is built around the bill structure. When I go on a consulting visit with a company, one of the first areas I ask to look at is there typical bill and bill structure. This tells me so much about how the product is currently being handled. I think as we go through the material, you will start to see where I am coming from.

4. Bill of Material Structure

All products that we use and come in contact with have a bill of material and likely have some type of structure associated with it. In this part of the course we will develop a sample bill structure. Initially this will be a very simple bill structure and we will not have any up front special requirements. As we continue through the bill structure we will start to see how the bill can be tailored to better suit the product flow requirements. Some bill structure requirements that we will discuss later are:

- "As built" requirements (for the shop planning and scheduling)
- Stocking requirements (both for new assemblies and the aftermarket, this applies to inventory)
- Cost rollups (How does the bill need to be structured for determining the cost of the product?)
- Standardization (How can the same sub-assemblies be used though-out an entire product line that has various features? Modular designs)
- Customer options (How do we structure a bill to address the wide range of customer options?)

At this point, take out a blank sheet of paper and follow along as we create our sample. We will create a structure for a lawn mower, something everyone is familiar with.

This will look like a company organizational chart with the president on the top. We will put the first item in the top block and call that the "lawn mower assembly" or "final assembly". This represents the finished product ready for shipment. We then draw lines down to three items which would be like the vice presidents in the organization. These items will be the three top sub assemblies in the bill which will be the engine assembly, the chassis assembly, and the handle assembly. These items are required to make the top item which is the final assembly of the lawn mower ready for shipment. As we develop the structure, you will start to see how the flow through the bill structure goes from the bottom up to make the final assembly.

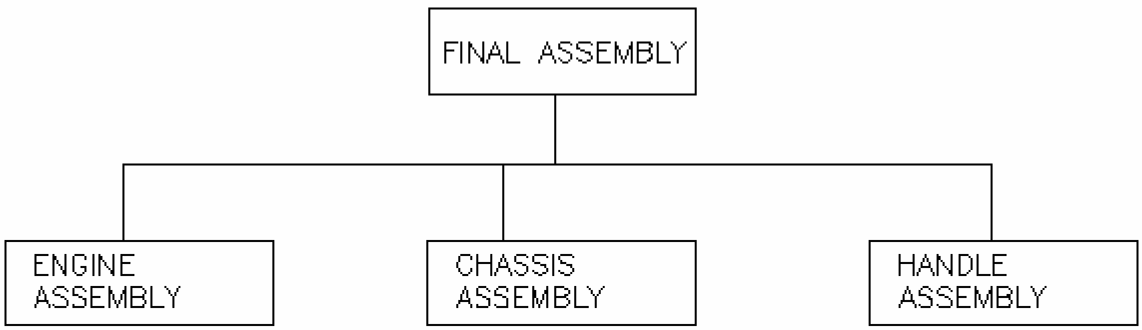

Figure 2 – Bill of Material Top Level

We need to stop here for an important definition. Each of these blocks that we create will represent a "part" in the bill. We classify bill parts as one of two types; make and buy parts. "Make parts" are manufactured and "buy parts" are purchased. All the parts of the bill are classified as either make or buy. Going Back to our bill structure of the lawn mower, we have to now classify the three parts on our top level. For this exercise we are going to assume we purchase the Engine complete so therefore it will be regarded as a "Buy" part. Label your sketch with a B for the engine. The handle assembly on the other end of the line would be considered a make part and therefore should be labeled with an M.

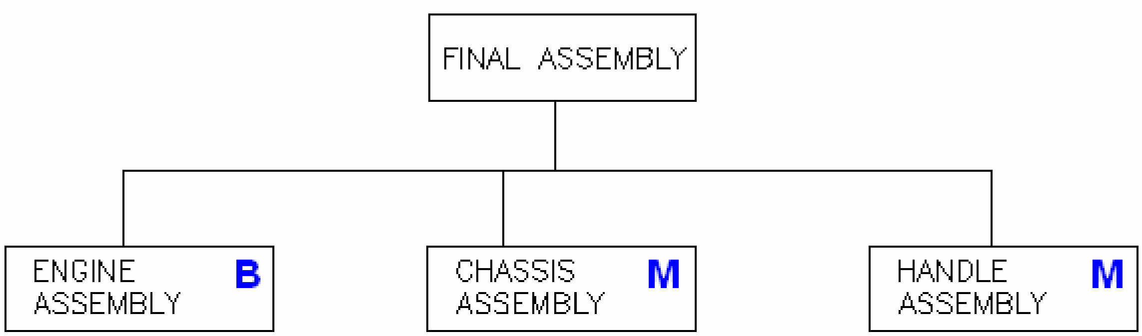

Figure 3 – Bill of Material Top Level w/ "M" or "B"

We will focus on the chassis assembly for the rest of our structure exercise because as you will soon see this structure is going to expand quite a bit. So for simplicity we will only break done the chassis portion of the bill. The chassis assembly is a make part.

The chassis assembly will now break down to three blocks that we will call the wheels, the frame, and hardware. The wheels and the hardware should be labeled as buy parts. The frame is a make part and further breaks down to two items called a blank and the wheel supports that get welded into the frame. Now in this example, I am picturing the blank as a formed frame not a flat sheet. We're not done with our structure yet. The blank should be labeled as a make part and it breaks down to one item called 7 gauge sheet metal. Draw a single straight line from the blank to a new block and put "7 gauge sheet" inside it. The wheel supports are make parts and should break down to a single block called 4 inch bar stock. The 7 gauge sheet and the 4 inch bar stock should be marked as buy parts.

Let's review the structure, before we continue. The final lawn mower assembly breaks down to three main sub assemblies; the Engine, the chassis assembly, and the handle assembly. The Engine assembly is purchased complete, so we do not have to go any further. The handle assembly is considered a "make" part but we are not going to go any further with it at this time. The chassis assembly, we broke down to three items; the wheels, the frame and the hardware. The wheels and hardware are buy parts, no further break down is required. The frame of the chassis assembly we broke down to the blank and the wheel supports. The blank is made with 7 gauge sheet and the wheel supports are made from 4 inch bar stock.

I know this seams complicated but the benefits of this exercise will soon be apparent. Compare your diagram to figure 4 and save it for reference later.

5. Characteristics of the Structured Bill

The following figure shows our completed bill of material structure.

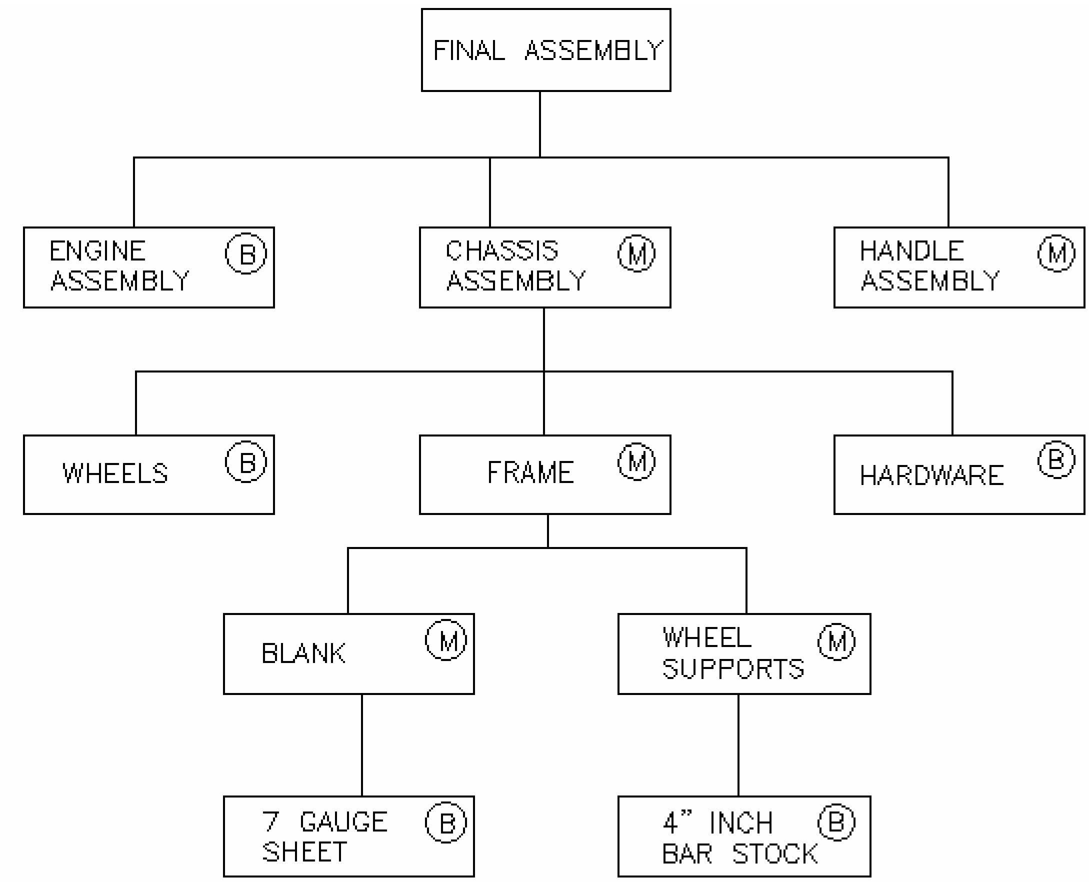

Figure 4 – Bill of Material Full Structure

The lowest level in any path of the structured bill is always what type of part? It is a Buy part. Why is that significant? If I am in Purchasing, I can look at our structured bill diagram of the lawn mower and focus on procuring all of the lowest level items of the bill. Remember, we said the parts start in the bottom of each leg of the bill and move up to the final assembly. Technically, all those items become the responsibility of Purchasing and Material Control, whether they are purchased new for the job or taken from inventory.

Earlier we talked about the drawings as "visual aids" to the bill. We can now take our diagram and link in the portions that require a drawing. I like to draw a line in between the levels and label it with a drawing number for that particular piece part or assembly. There may be more than one drawing required. For example, an assembly and a schematic may both be required to create a hydraulic or electrical assembly. Therefore in that particular case, we would list two drawings at that point in the diagram. They both become the visual aid to take the bill from the level below to the next level up. This diagram now becomes an excellent tool for communication between the various departments that deal with the product flow. Manufacturing may indicate to Engineering, “Hey, I need a drawing to build this part of the assembly, and point to that portion of the diagram.” Planning the drawings for the product **after** the bill is roughed out is a very efficient way for Engineering to operate, especially on new products. You can have a planning meeting where a new product concept is developed and create a bill structure of how it will be made and how it will move through the plant. Then the necessary drawings can be identified on the structure. This is a very effective way to handle new product development. It keeps Engineering focused on creating only the necessary drawings for production.

The bill structure becomes an excellent planning document. The bill represented in this format becomes an excellent panning tool for production. As we go from one level to the next in the bill, work instructions or routings are many times required. The routings can be referenced right on the diagram, in between the various levels of the bill. The shop can now plan the necessary time and resources for each level of the bill and then develop their overall plan to execute the entire project. This is where an “as built” bill structure becomes important. We will discuss more about “as built” a little later.

- *SUMMARY OF THE KEYPOINTS COVERED SO FAR* ------------------------

1) **Bill of Material Structure** -My experience with production improvement committees has been that the details and structure of the bill of material is an important area to address and make change. In the above sample structure, we broke down a lawn mower assembly and I think you could see how it starts to expand. I was involved with some task force committees were we did this for much larger assemblies and covered the walls with these structures. But as we did the structure we saw areas were improvements could be made, we made changes that would affect our efficiency.

2) **Product Flow -** Other items we covered so far are, . . we discussed the “product flow” through a company and talked about how it moves from one department to the next. I think each company and each product has its

own natural product flow. Is it correct? Does it need to be changed? As you start looking at your bill structure you may feel changes are required.

3) **Engineering Deliverables** - Another item we covered was the Engineering deliverables for the other departments. This covers what is produced by Engineering and given to Manufacturing and Purchasing, and maybe Sales or Marketing.

4) **Make and Buy** - As we finished with the development of a sample structure of the lawn mower. We covered the part classification of "make and "buy". In the past, one of the questions I received about classifying all the parts as make or buy, is. . . what about linking information into the bill like drawings or other reference information? These types of items are sometimes referred to as phantom items. You could add these items in as a separate block in the structure, but my opinion is to keep this to a minimum. With today's production control systems, there are plenty of ways to tie special drawing numbers and other information to the bill without adding a block to the structure. This can avoid unnecessary detail.

***** Production Example – Press Platform *****

I was working for a company where we produced large presses and press systems. The crown (top structure of the press) required platforms and railings around it for servicing. In the past, the platforms and railings were scheduled to arrive late in the assembly stream, after the crown was stacked on the press. We looked at this and realized that if we assembled the platforms earlier on, they could be useful for completing the assembly of the crown. The assembly staff could use the platforms for a great deal of the assembly work, before the crown was stacked. We then changed the flow to have the platforms and railings added to the crown earlier in the process. Now the majority of the crown assembly could take place at floor level utilizing the platforms. This produced several benefits like safety, tied up the crane less, and it reduced the overall schedule. This was a definite change to the bill structure that produced benefits.

- - - Covered Next - - -

The next part of this class will cover several items that can be added to the bill and several uses of the bill.

6. Adding Routings to a Bill

To demonstrate how a work instruction or routing ties to a bill structure, lets go back to our lawn mower and focus on the level were the frame is called out. Below the frame we have two items, the blank and the wheel supports. The blank is a formed piece that now requires four wheel supports to be welded in place. The steps for the process might be as follows. These are primarily welding steps.

- Position wheel support in 3 inch bore of the frame
- Place two small tacks on each side of the support on the outside of the frame
- Inspect the setup to confirm there is no clearance between the support pilot diameter and the side of the frame.
- Fully weld the outside with the proper fillet weld size.
- Fully weld the inside of the frame around the support using the proper fillet weld size
- Repeat the process for the other three wheel supports

At the completion of these steps the frame has now been created. This routing can now be linked to the bill between these two levels. The time associated with the above routing also shows up at this point in our process. This becomes important as we start to use the bill for resource planning and scheduling. As you look at the bill structure in this manner, the product flow goes from the bottom up. At the lower level you have the blank and 4 wheel supports. Now you apply the routing we just discussed to create the upper level, which is the completed frame assembly.

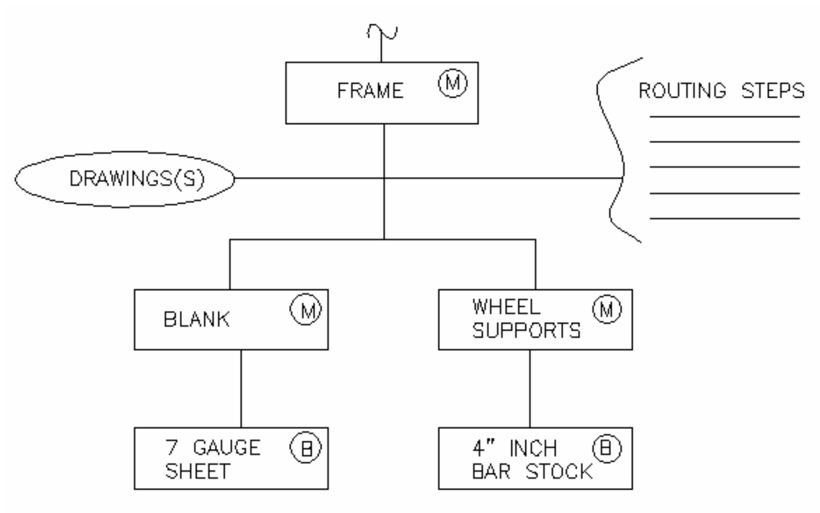

Figure 5 – Addition of the Routing

Technically, everyplace in the bill that represents a “make” part a routing of some type is required. Someone must apply labor to create that part. The work center where the routing takes place will vary depending on the routing steps. Our example above takes place in a welding work center. Other routings could take place in departments like assembly, machining, finishing or polishing. The work center were the routing is executed becomes important when we discuss resource planning and scheduling.

** ***Production Hint*** **

Most production control systems have provisions to add routings. The routing steps usually require a number for each step. When the routing is built for the first time, a good approach is to increment the step number by 5 or 10. The first step would be numbered 10 the next step would be 15 or 20, and so on. The reason for this is to allow for additional steps to be inserted later. Since a routing is very sequential in nature, you want to be able to insert steps where they are required and you don’t want to go through renumbering each time you make a change.

7. The Importance of the "as built" Bill

Creating a bill of material can be done using several different philosophies. Sometimes, the bill is created for the specific needs of one department. For example, Engineering may feel the bill should be broken down by discipline. They may choose mechanical, electrical, pneumatic, and hydraulic to be the top level of the bill because this may be the way the project is broken done in the Engineering department. However, this is likely to be little use to the rest of the company because it does not represent the way the product is manufactured. It does not follow the "product flow".

If the bill is to follow the product flow, it must represent the way the product flows through the shop. We should be able to work our way up each leg of the bill to the complete final assembly the exact way it flows through production. This is what is meant by an "as built" bill of material structure. A bill structure in this format now becomes useful to many departments.

If we go back to our lawn mower example, we can discuss a new addition to the bill and try to determine where it fits in, to maintain an "as built" structure. The blade of the lawn mower is obviously an important part of the assembly. Without it the lawn mower may not function very well. Where does the blade belong in our structure? Note that we cannot assembly the blade until the motor is mounted on the frame.

The blade belongs on the top level with the engine, chassis, and handle assemblies. With the blade located here on our structure, the proper scheduling and resource planning will take place to be sure it shows up when it is required, and not too soon in the process. This example shows how important an "as built" bill is to just in time planning. Our example is a simple case, but if you think of a product with a longer lead time, having the parts show up long before they are required increases inventory and creates inefficiencies. With this example, I think you can start to see how the scheduling requirements of making a product tie into the bill structure. The blade manufacturing needs to be timed so that it is complete when it is needed in assembly.

Some organizations maintain more than one bill for a particular product. Sometimes it is referred to as an Engineering bill and a Manufacturing bill. This tends to add to the maintenance requirements. With two bills to maintain, the work is doubled. It is best to keep one bill and make it an "as built" bill. As we said a few minutes ago, the bill in an "as built" form becomes useful to more groups in the company.

** ***Production Hint*** **

In some cases, a second bill, or a portion of a second bill, may become necessary. This is the case if during producing a product, a substitution by Manufacturing or Material Control is desired. For example, let's say we are making our wheel supports for the lawn mower. From our bill structure, we require 4 inch bar stock to make the wheel supports. If we are temporarily out of 4 inch stock but we have 5 inch stock, we may want to make a temporary substitution. This would only be temporary because it **will** add some machining time. In this case, the decision to add machining time may be selected to keep us on track with the schedule. It will get us out of a jam. To make this substitution, some method within the production control system is required and it may be a change to a secondary bill. The best production control systems allow for these types of situations because, as you know, it is the real world case. From time to time, you will need to make these types of substitutions. If you are evaluating a production control system for your company, you want to be sure you evaluate how temporary substitutions are made.

8. Integrating the Bill with Scheduling

We discussed adding routings and we covered "as built", now is a good time to talk about scheduling.

The typical method that everyone likes to use for scheduling is the Gantt chart. The Gantt chart was first created by Henry Laurence Gantt in 1910 as a scheduling and project management tool. The chart is basically a list of tasks along the side of the page and a timeline across the top of the page. It shows when certain tasks need to be competed to maintain an overall delivery of the entire project. The project could be a product or it could be a construction project, or really any activity that you want to plan. Gantt chart planning has become the standard for controlling all major construction projects like bridges, major buildings, and highways.

When we apply Gantt charts to plan a product, we can use the "as built" bill of material structure, the routings, and the purchased parts lead times. In the same way we break down the bill structure into sub assemblies, we need to do the same for the scheduling. We would look at each block in the bill and assign a required resource and a time to do it. In this case, each block becomes a "task" in the Gantt chart.

In our lawn mower example, the frame is broken down to two items, the blank and the wheel supports. The blank has some material required, which has a lead time. And the wheel supports have a material requirement of bar stock that has a lead time. The routing we discussed above was for turning the blank and the wheel supports into the frame. Likewise, there is time required to complete this routing. Our Gantt chart for this part of the bill could take the form as follows:

- 7 gauge material	16 hours (This is the time required to procure the material. I am deciding to use "hours" as the units for our timeline. Hours will be carried throughout our timeline.)
- Blank	1 hour
- Bar stock	12 hours
- Wheel support	5 hours
- Frame	3 hours (to execute the routing we discussed above)

An important item in Gantt chart scheduling is called "linking" the tasks. The blank and wheel supports must be completed first before we can begin creating the frame. Therefore, these tasks are "linked" to the frame, which means they must be created first. Since you need 4 wheel supports, we may need to link the four of them together, if they are made in one lathe. That means they must be made one after another and the total time would be 5 hours times 4, or 20 hours total.

As you build the Gantt chart, you start to get an idea of the total time required to create the frame part of the bill. Now we said the 7 gauge and bar stock required time to procure. If these items were stocked, as they probably would be in this case, those times would drop out of the Gantt chart or certainly be reduced.

One other important item about scheduling is the resource requirement. The resource is the department or work center that must allocate the time for completing the task. The task of making the wheel supports requires a lathe operation, and we cold define that task resource as "Machining". The routing steps we presented to make the frame where primarily welding steps, we could define the resource for that part of the schedule as "welding". So as we add tasks to the Gantt chart, each one requires some resource definition and these are adding in to the schedule.

Now as you build these schedules and you put in times and resources, you start to build a capacity plan for creating the product. If you do this for all the products made in the shop, you can get an entire capacity plan for the shop, or even expand the plan to cover the other departments in the company like Engineering, Process Planning, and Material Control. The Gantt chart can be filtered to show the requirements of a single department or work center. For example, the machine shop tasks could be isolated to show requirements of that work center. If you develop your schedules by specific machine shop work centers (like lathe work for example) you can see the requirements of just that work center. This can really identify the bottlenecks in your organization and adjustments can be made. Our example of the wheel supports puts a heavy demand on the lathe work center. Remember we said we had to run the supports one after another for a total of 20 hours? Definitely, a second lathe and operator could reduce the cycle time and possibly reduce a bottleneck in the flow.

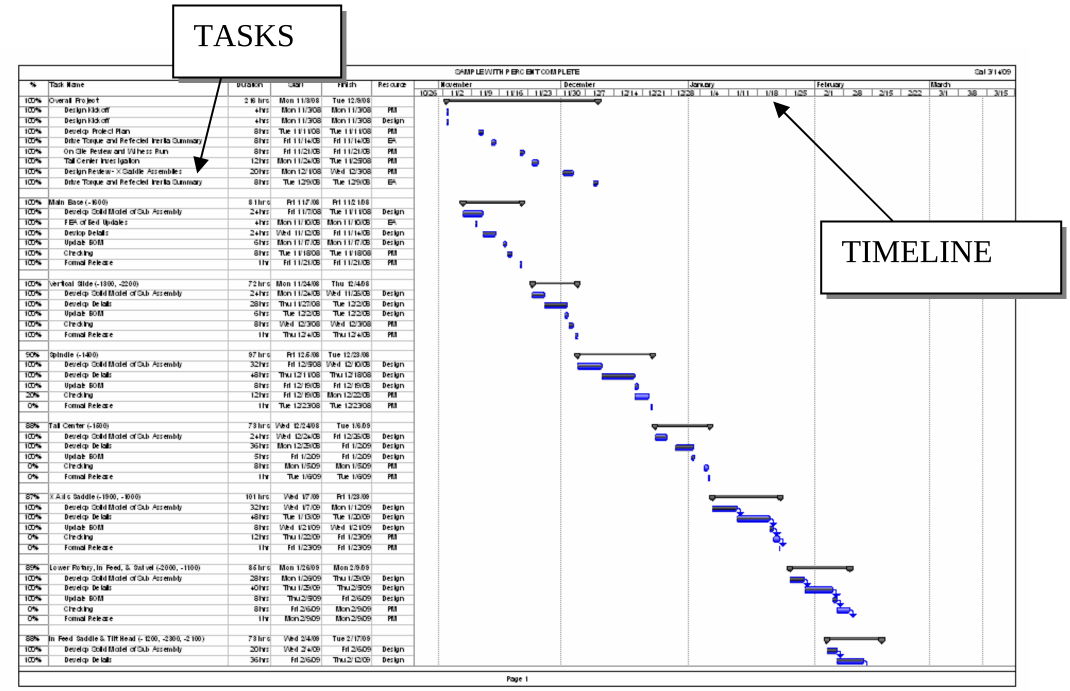

Figure 6 – Sample Gantt Chart

** ***Production Hint*** **

The computer program most often used for Gantt chart scheduling is MICROSOFT PROJECT. It has tremendous capabilities for looking at one or more resources and can really help automate the process of scheduling. The modern day production control systems incorporate all aspects of the business and integrate the bill structure, the routings, and the material lead times into one system with the scheduling. So you can get your capacity plan in the production system and you may not need to get a separate scheduling program.

9. Inventory / MRP and the Bill

So far we discussed the steps required to develop a structured bill. We showed how drawings and routings can be added to the structured bill diagram and we discussed the importance of having a single, “as built” bill to represent the product. When we talk about using the bill for inventory and MRP, we need to introduce two new topics, part numbers and units of measure.

Part Numbers

Each item of the bill requires a unique part number. The part number can be the same as the drawing number. For a make part, this is probably the best decision. If you are creating a part number standard, you should include representation from all the departments. As we have established, the bill of material is a company document that is most effective when it is understood and used by all.

Putting logic in the part numbers could be a difficult thing and may not be as necessary as it was in the past. With today’s production control systems, the item master database can be searched for groups of parts based on description without too much trouble. Maintaining complicated logic in the part number may over complicate things.

I remember working with a part number that had logic built in for a series of milling blades for a processing mill. It became so complicated, as new blades were created it became more difficult to figure out what part number to give the blade than it was to create the new drawing. The number included a combination of letters and numbers that were intended to give you all of the parameters of the blade. The machine size it was for, right hand or left hand, and so on. In this particular product line, new blades were created all the time. A sequential number would have been a lot easier to manage. Every time a new blade is created, just grab the next number. The benefit of having a number with logic built in, is so that looking at the number you would get a complete description of the part. My argument is that the advantage is outweighed by the maintenance and cost to create the number. Use your production control system to give you the description with a key stroke and avoid all the headaches.

Units of Measure

Units of measure is an important item on the bill of materials. In many cases the units of measure is simply the quantity of the item. In our lawn mower, the chassis assembly is made up of the wheels, the frame, and the hardware. We require 4 wheels so therefore the units of measure for the wheels is 4. Units of measure, other than quantities, are used and typically show up in the lower level of the bills. The 7 gauge sheet to make the blank could have units of square inches or pounds. Now when the bill is used in production planning, the requirement for the blank will call for a certain amount of 7 gauge sheet based on the units that show up in the bill. It is important that the inventory units of the sheet match these units. If there is a difference, we could get the wrong amount of material allocated.

For example, if we inventory the 7 gauge sheet in pounds and require 900 square inches to make the frame, the system may not deal with this difference properly and may supply 900 pounds for a single frame! This is obviously much more than we need. The best way to inventory the raw material is to use the same units that we use in the bills. If a conversion is required, it should be done at the time the raw material is received. This could avoid problems later. This is a real world type situation. Your design and execution of the use of the material could vary from the way your suppliers produce and ship it. Many times it does. The best rule is to deal with it when the material arrives at your plant. Make the conversion **before** you assign it to your part number and put it into your inventory.

Earlier, we covered using the bill together with a scheduling system like a Gantt chart. The leads time of procuring the material where added into our schedule so that the right time was allocated. The decision to stock raw material, or other items from our bill for that matter, needs to be made with this schedule in mind. It is not always an easy decision. The safest approach is to stock everything you are going to need. However, the cost of keeping a large inventory is significant. I heard a phrase once that “inventory is evil”. Some of the strategies for improving the production efficiency involve going after the inventory and trying to reduce it. This philosophy led to the programs of MRP and Just in Time planning. If fact, one of the key parameters that Material Control managers track is inventory turns. The question they deal with is “Is my inventory turning over enough or am I buying at a higher rate than I am shipping?” This helps them get an overall indication of how high or low the inventory is.

To make an improvement in the inventory level, the tools of an “as built” bill and the Gantt chart schedule must be used. With the proper review, the items that can keep your schedule where it needs to be will be stocked and nothing more. The concept of “on hand balance” for a particular item is one that constantly needs to be looked at. The “on hand balance” is basically your current level of inventory for a particular item, expressed in its proper units of measure. Like many things, it takes several small steps of improvement to effect the overall picture. In our case here, it is an item by item review of the buy parts of the bill. If we can reduce our on hand balance a little here and little there, we will eventually see the inventory turns improve. So. . . the question for us is. . What do I need to have on hand for this one particular item to stay on track with the overall schedule? Sometimes it is like predicting a magic number. If the “on hand balance” goes negative, that indicates a shortage, if it stays positive consistently, that could indicate too much inventory is on hand. The key is to time the arrival of material from your suppliers so that it is there when you need it. It takes constant review of the bill structure together with the schedule.

In our example above, we developed a schedule for making the frame assembly of our lawn mower. This schedule included lead times for the 7 gauge sheet and the bar stock. I think it is clear we would not want to hold up the schedule of the lawn mower to wait for these two items of raw material. We want to have them “in stock” on the shop floor. But, . . How much do we want to have? How much should our on hand balance be? The proper determination of the stock amount depends on how many frames we are producing and how many we plan on producing in the future and at what rate. This sales forecast will be a key component in determining our “on hand balance”.

This whole topic of addressing inventory may seem a little outside the scope of this class. But when you start to realize how the schedule and bill structure are integrated you can see how important they are to addressing the inventory on an item by item basis. What if the design and bill used more common parts? Wouldn’t that make our effort of analyzing the inventory easier? Of course, there is less to analyze. Also, if Purchasing had to buy more of one item in place of buying smaller quantities of two items, then they see an advantage of quantity discounts. Using common parts falls into the bigger topic of standardization which I will cover later.

Another example of how the bill structure affects inventory is when we want to stock a portion of a product or a sub assembly. This may be done to help remove time from the overall product cycle or it could apply to a demand from the aftermarket. Assume we are making DVD players and we want to stock the mechanism that ejects the disk. For this case, we will need to structure our bill so that the eject mechanism is in one leg of the structure and it has its own part number. Under this part number will be all the parts, drawings, and routings to build this assembly. In the ideal case, this complete assembly can be stocked under that number. In the future, when the demand shows up for that assembly, that particular part number can be allocated from the inventory to fill the need. This would apply to a new DVD player or a repair in the aftermarket.

Many products have components that need to be replaced from time to time. These are referred to as “wear items”. If you manufacture clutches or brakes, the friction discs will typically have to be replaced after so many hours of use. These discs may include some additional support components much like the discs for your car brakes. They are molded onto a metal frame. In this case, the replacement discs will have a small bill of material under them to represent the metal frame and the friction material. There will be a routing to join the two together and form the new part number of the completed disc assembly. The best approach for addressing this aftermarket demand and the new product requirement is to have a single part number for both cases. This eliminates the need for having a special bill structure for the aftermarket. As you structure the bill, this is another item to take into consideration. We want to maintain an “as built” bill and we also want to be sensitive to the aftermarket demands.

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Our next topic is the finance department’s use of the bill. The units of measure, which we covered a while ago, will be important to determine “how much does the product cost?”

10. Finance and the Bill

We have discussed "as built" structure, how to add routings to the bill, and the importance or units of measure. All this items come into play when we want to do cost roll-ups to determine how much the product cost as a whole or how much a portion of the product costs. The cost roll-up will follow the flow of the structure much like the flow when the product is manufactured. For the buy parts, the system will assign a dollar amount to that block in the bill. That would be the cost to buy that particular part. If multiple quantities are needed in that assembly, the quantity is applied to the dollar amount.

In our example of the lawn mower frame blank, we said we need 900 square inches of 7 gauge sheet. If the cost of the sheet is 3 cents per square inch, the cost of the material for the blank is, .03 x 900 = $27. Now to turn the sheet metal into a blank for the frame, we need to apply labor. This is where the routing comes into play. The routing steps each have a time associated with it that is charged at the rate of that department or work center. Combining the labor cost with the cost of the material will give you the cost for the frame. As you work your way up each leg of the bill, you can get a cost associated with each sub assembly of the product. Finally, as you continue the roll-up in this manner, you will reach the final cost of the product.

In the previous section, we discussed the selling of a sub assembly for the aftermarket. The cost for this sub assembly can be determined by doing a cost roll-up up to that part number. With today's production control systems, this can usually be determined in the finance module of the program by a simple query. To get an accurate cost, all the data below that part number must be correct and up to date. The buy parts must have the accurate cost in the item master and the routing steps must have accurate times listed.

As products are designed and built, there usually comes a time when you want have a design review with the objective to reduce cost. A good way to do this is to get representatives from Engineering, Purchasing, and Manufacturing together, layout all the drawings, and have a brainstorming session to address the issue. Traditionally, this is how most of the design reviews take place. Everyone sits around the drawings and say things like, "that part of the machining takes for ever, it requires three setups! . . . What can we do to change that?" or if it is someone from the material control part of the business, they may say, "you now vendor xyz has just raised his price again for that cylinder, can't we do something different?" You end up with alot ideas, good ideas, coming from different areas.

A more direct way is to do it with the cost roll-up data. Take the bill structure and look at the cost of the top level items. As a **group**, focus on the more costly items and follow them to the next level of the bill. Keep the discussions “fact based” using the cost roll-up data. Continue in this manner to get the most bang for the buck. With all the disciplines present, new designs and methods will be identified, all the time with focus on the “as built” bill structure and the cost of each leg of the bill. When the exercise is complete, the group will have a much better understanding of where the cost is than if only the drawings were used. This should produce results that are more targeted to the objective of cost reduction.

In a cost review like this, you definitely want to have all the groups present. Representation from the shop and Manufacturing is essential. The idea here is to do it in a more organized manner using the bill and the cost data. The cost cutting committee usually may not be able to finish in one meeting. It may require several meetings and the group could have different representatives for the various meetings. Using the bill, you can plan the agenda and select the members as required. If you are discussing a portion of the bill that includes all machining operations, you will want to include the machine shop foreman… for a portion of the bill that is primarily welding, you want to include someone who is close to the welding operation, and so on.

11. Standardization and Modular Design

This next section will refer to standardization and a term that you here a lot, modular design. What is modular design?

When I think of modular design, my experience with a job I had demonstrates this characteristic. Years ago, I worked as a radio installer at a stereo shop. We put car radios in new cars from the dealer and also a lot of used cars as well. The radios back then had radio shafts that had to fit inside a certain cavity in the dash and they had to have a certain cord dimension between the shafts. The radios for the cars back then were very specific. Only certain radios would fit in certain cars.

Today, the radio designs are a lot different. The requirement for the cord dimension of the shaft does not exist. In many cases, the opening in the dash is a large rectangle rather than the way it was before which was two circular holes cut in the dash for the shafts. The radio shafts are part of the radio and do not fit through any opening. The radios are a lot more interchangeable between car models. This design has become a lot more modular.

To explore this concept further, we need to talk about the common challenges with delivering "made to order" products. In many of these cases, the product becomes very custom. The customer has specific needs and this is reflected in the specifications. The specifications tend to require new bills to be created with many new part numbers and drawings. Although the product may have similarities to an existing design in the company, it tends to become a special.

A "special" requires new part numbers and new drawings. This adds to the cost and the maintenance of the bills. In this situation, the strategy to become competitive is to address the objective of "how do we give the customer what he wants by using existing Engineering or designs?" Although the design for his requirements does not already exist, there may be ways to structure your bills of materials so that portions of the existing designs, or sub-assemblies, can be reused.

Let's walk through this exercise. The process starts by getting an understanding of which parts of the design are sensitive to the customer's requirements and which parts are not. A great way to begin, is to set up a matrix of an already existing design, one that is similar to the new design. In other words, it will have most of the same features but with different technical specs like size, capacity, and so on. This quite often is the actual case. This existing design is sometimes called the “reference job”.

Along the top of the matrix, you list all the major sub assemblies in the design, using your bill structure. Along the side of the matrix, you list all of the customer specifications. Examples of the customer specs might be things like stroke, speed, etc. The next step is to review each specification against each major sub-assembly and determine if the sub-assembly would require a change for that specific spec. If it does, you put a 1 in the square and if it does not you put a 0 in the square. Complete this process for each specification comparing it to each major sub-assembly. If you are fortunate to have an entire column of zeros under a particular sub-assembly, then that indicates that subassembly is un-affected by the customer specifications. You can say that sub assembly is standardized.

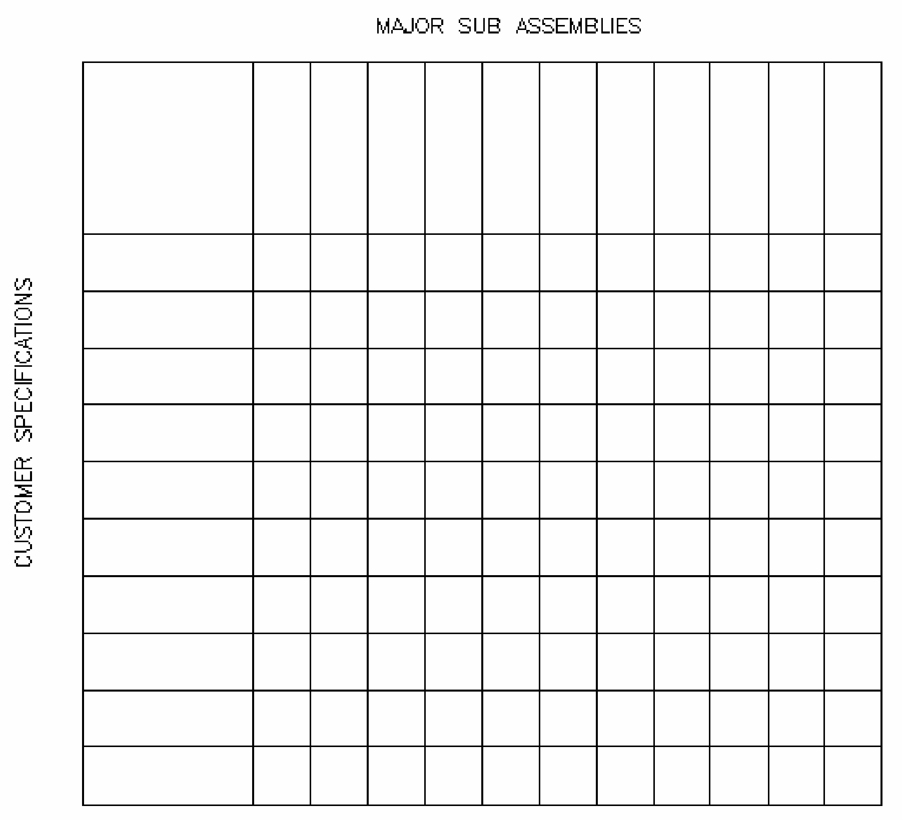

Figure 7 – Standardization Matrix

However, in many designs you do not achieve this without some investigation and revisions. This is where the review of the bill comes into play. The objective now is to look for minor adjustments to the bill in order to create independent subassemblies. In addition to a bill change, maybe a slight design change is required as well. If you can achieve this through a revision, the design becomes more modular.

Let's talk this through with an example. Suppose we are making an automation device that has an index mechanism. The mechanism is made with a gear motor and a slider crank linkage. Between the gear motor and the slider crank mechanism, there is a timing belt and pulleys that produce the final rate of the index. For simplicity reasons, we are using a constant speed gear motor and do not want to vary the speed with a frequency inverter. Let's further say that typical applications for the index mechanism require an output of 30, 45, or 60 indexes per minute, depending on the application.

Because of our "as built" requirements, we have two sub-assemblies, one for the gear motor assembly with its support structure, and another for the slider crank assembly and its support structure. One way to structure the bill of material would be to put the pulley for each half of the assembly with its respective sub-assembly. If we think of that in terms of our matrix, what have we done with our relation to the specifications?

Both sub assemblies are tied to the index speed requirement. If we want to create a standard, modular sub-assembly, we need to somehow break that relation. We need to move the timing belt and pulleys higher up in the bill so that these two sub assemblies are unrelated to the index speed requirement. Applying our matrix analysis to this, the squares for each assembly would now change from a 1 to a 0. This is a way we could make these two assemblies modular.

Another topic under the umbrella of standardization deals with the use of individual parts and components. A while back, we talked about using common parts and how it would help address our effort to minimize the inventory. This strategy needs to be implemented early on in the design of the product. It requires Engineering to be sensitive to which components and which parts are put in the design. Engineering will need to use careful consideration when new parts in the system are selected. Each new part that is added should be contemplated as follows. If it is a valve for a new design, The Engineer of the project should ask . . . "Can a valve we already have in our database be used in this new design, or do we really need to go to a new one?" Sometimes an item like new hardware is an easy target. If Engineering can get into the habit of looking at the current hardware in the database, sometimes new size fasteners can be avoided. To formalize the process more, the philosophy of evaluating all "buy" parts in this manner should be considered. Getting the most out of common parts for the most part falls into the responsibility of Engineering. This is where the design is created. In existing Engineering departments, this approach sometimes requires a little bit of a culture change.

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I want to continue with these concepts of modular design and standardization and broaden it to cover the more general case. How do we structure our bills to cover a wide range of possibilities across an entire product line? I like to call this section dealing with the customer's options.

12. Customer Options

In the last example, we talked about how we would modify a bill to create two modular sub assemblies. By moving the timing belt and pulleys higher up in the bill structure, we satisfied the requirement for the index speed, separate from the drive assemblies. We can apply this thinking to the entire product line.

For the prior case, we dealt with one specification for one particular machine. When we want to discuss an entire product line, we can use the same approach with the matrix, but now include not only the existing specifications, but try to add all the possible specifications. A simple way to put this is, "today, the customer needs one of three possible speeds, what will he need in the future?" What other requirements will he have?" In most cases, Engineering will require the assistance of Marketing to address this. As the new requirements are identified, Engineering will need to go through the same exercise of reviewing the bill and the design to determine the most effective way to set up the structure.

This part of the process takes a lot more foresight than the analysis of the current day case. Once you have the specifications in front of you, the matrix analysis becomes very straight forward. The creativity comes into play when you want to make the adjustments to create the modular designs. When you look at the bigger picture and try to imagine what specs **will** be required, the task is a lot more difficult. The marketing direction is necessary to help fill in the blanks. Sometimes, the best approach for production is to try and produce scenarios where the design and bill is as flexible as possible, and then these concepts are presented to marketing in this manner. "If we create this type of design, we can allow for all these options. What do you think? Will the customer want this capability?" The teamwork between marketing and production here is essential.

When we talk about the customer demands and options, we also have to address . . What about the schedule for delivery of the product? My experience has been the customers want a product that meets all their requirements, no matter how special it is, . . but they also want it in short delivery. Using the approach with the matrix review can help you identify sub assemblies that can be stocked ahead of the time of order. If we go back to our example of the index mechanism, you can see that the new bill structure would allow us to conveniently stock our two sub assemblies. This would give us a much more competitive delivery. Now when the customer orders a unit with a specific index speed, the only new requirements are the timing belt and pulleys.

The question of “what to stock and what not to stock” is a critical issue. When we discussed inventory earlier, we emphasized the need to keep inventory at a minimum. We do not want to add to inventory without the proper forecasting. However, the point I am making here is that if stocking is going to be used to improve delivery, it can be more effective with a more modular bill structure.

Obviously, the concept of the index mechanism is quite simple, but it does demonstrate the issues and a way to approach them with the bill structure. If you apply this method of approach to a more complicated product, the solutions will come out.

13. Maintenance of the Bill

The final topic I would like to touch on is the maintenance of the bill. With the all the topics we covered, I think the need for good data in the bills is obvious. When we discussed scheduling, the requirement of accurate routings became apparent. The lead times for the purchased parts is important for scheduling and also for our determination of "on hand" balance. The cost data in the bills must be accurate in order to achieve meaningful cost roll-ups. And of course, the structure of the bill must be accurate to properly represent the flow through production and also for use in design reviews and cost cutting reviews.

How to achieve accurate bills requires a careful review of the responsibilities and a company organization that covers the many aspects of the bills. One way to do it is to list out all the requirements and determine who will be responsible for what. For each part in the bill, there must be some type of an "item master". If it is a "buy" part, the item master will contain all the lead time and the cost information. In most organizations, Purchasing or Material Control would take on the responsibility to keep these item masters up to date. Vendors typically change there delivery and cost every so often. Those updates must be made to the "buy" part item master.

For "Make" parts, a routing of some type is required. The routing information usually falls into a group that does process planning and may be part of the Manufacturing organization. This group or person will have to be responsible for keeping the routings accurate and up to date. Sometimes, time studies are done to evaluate the times of the routings. This responsibility is usually covered by an Industrial or Manufacturing Engineer.

Keeping the structure of the bill to conform to an "as built" flow, may require more than one department. It could require a joint effort between Engineering and Manufacturing. It may have to be modified after the product is made, especially in the case of a new product coming out of the R & D portion of the company.

The execution of change control needs to not only cover the drawings that are produced, but also the bill structure and bill details. This falls into the company Change Notice policy. There should be a designation on the CN form that designates which department will make the necessary update. If it is a quantity or structure change, this may fall into the responsibilities of Engineering. If the CN covers the cost and lead times of a purchased part, this may indicate a requirement for Material Control to perform the revision.

Since most companies today operate with a computer production control system, the topic of bill of material maintenance has to be covered here as well. The systems usually have security parameters that only allow for selective write capabilities. This is where the responsibilities of maintenance can be defined. Engineering may have write capability for the bill structure and item master definition, but not for entering the lead times and cost data. That information may only be entered by Purchasing or Material Control. Likewise, the routings would be entered by Manufacturing. In this way, the maintenance responsibilities can be defined.

How often the bills are updated for maintenance issues is harder to pre-determine. We can define who will do the updates, but how often should the bills be reviewed for accuracy? The best case may be to have the bills reviewed for accuracy every time they are released to production. In other words, after a structured bill is released to production, the lead times, costs, and routings are all reviewed for accuracy. This review should include a formal approval process by the group that is responsible. But what about the aftermarket requirements? These requests may not be part of a formal release process through Engineering. There needs to be a procedure to review and update bills not only for new product releases but also for aftermarket requests. Certainly a change in price or delivery by a vendor should signal an update to your corresponding “buy” part. If a vendor formally notifies you of a change in this area, it should generate action in your organization to do the corresponding update.

Keeping the Bills accurate is probably best described by the phrase “garbage in gives garbage out”. We require so much from the bill and the bill structure we can’t afford to have bad data. So much can be accomplished by focusing on the bill, but we need to have policies and procedures to be sure they are accurate and up to date.

14. Closing

In our class today, we covered many aspects of the bill of material. I started by talking about the product flow through a company and how the bill is used by all. The bill becomes a common document that is used by Sales, Engineering, Purchasing, Manufacturing, and Finance. I hope I have been able to demonstrate the importance of the bill for design, planning, scheduling, and cost review. With regard to the product flow, the bill becomes the roadmap for the product flow.

We discussed some ideas for conducting design reviews using the bill as the primary document. We also discussed some methods for converting and creating designs that are more standard or modular.

At the beginning of the class, I brought up the question of "who should create the bill?" My opinion, is it should be initially developed by Engineering. The data of routings, lead times, and cost would follow from the other departments in the flow. I believe Engineering needs to take the lead of the bill development in parallel with the development of the design.

The pressure for continuous improvement in efficiency will always be a part of production. The climate of our global marketplace demands it. Getting back to the basics of the bill of the material is one way to address this issue. This method provides for more positive and fact based communication across department functions. I hope through this class I have been able to demonstrate how effective this can be.