Finn-Power Italia Develops and Implements a Method to Cope with High Product Variety and Frequent Modifications

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Finn-Power Italia produces automated machines for sheet metal bending, which it sells in more than 60,000 configurations, obtained by combining several options. Furthermore, designers often modify the product. Bending machines can produce very different products, from baking ovens to panels for ventilation systems for cruise ships. We developed and implemented a method of using planning bills and product modularity to deal with high product variety and frequent modifications. Planning bills are an artificial grouping of components used to simplify forecasting and material planning. The method develops (1) decision-support models that simultaneously translate sales specifications for new or changed options into product documentation, and engineering changes into saleable options; and (2) planning bills that need not be fully revised as products change.

Key words: industries: machinery; organizational studies: decision making.

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The Finn-Power Group was founded in 1969 by Jorma Lillbacka as a small subcontracting company in Finland. Today it is the largest machine-tool manufacturer in Scandinavia, an international industrial group with over 1,200 employees. Finn-Power is an industry pioneer in developing and producing automated machines and manufacturing systems for punching, shearing, laser cutting, and bending sheet metal. It obtains some 88 percent of its annual revenues from exports to over 50 countries. Its most important markets are Western Europe, North America, and the Far East. It manufactures products in five plants in Finland and in one facility in northern Italy that specializes in bending automation (Finn-Power Italia). Finn-Power Italia is a medium-sized manufacturing company that employs 300 people, although it is one of the largest in its field in Italy. The company assembles automated bending machines to order from preassembled parts.

Bending machines can produce very different products, from baking ovens to panels for ventilation systems for cruise ships.

In particular, we focus on the express bending (EB) cell, a family of fully automatic bending machines whose rotational manipulators work the edges of metal panels, starting at the outside edge of the sheet and continuing inwards, working one side after the other in sequence until they complete all the bends. For instance, this sheet metalworking process allows the company to produce components for refrigeration systems (for example, condensers and evaporators) and household appliance shells. The EB product range consists of around 60,000 end-product configurations. Finn-Power Italia is known for the quality of its products and for its ability to customize automated bending machines to meet customers’ needs. The firm frequently modifies products in response to requests gathered by salespeople. Designers sometimes suggest product changes to improve products’ performance. The combination of high variety and frequent product changes complicates the task of aligning sales and such operations activities as purchasing, production planning, and engineering.
We developed and implemented a method of using planning bills (artificial groupings components used to simplify forecasting and material planning) and product modularity to deal with high product variety and frequent modifications. The method makes it possible for Finn-Power Italia to develop

1. Decision-support models that simultaneously translate sales specifications for new or changed options into product documentation, and engineering changes into saleable options; and

2. Planning bills that need not be fully revised as products change.

The research project started in January 2000. One of the authors made the initial contact with university as she was planner at Finn-Power Italia. The project team included the two authors and managers of the production-planning, engineering, and sales departments.

The Limits of Finn-Power Italia’s Existing Practices

Like many companies producing a large variety of products, Finn-Power Italia has difficulty forecasting demand for its many end products and variants for a long planning horizon. In 1999, it launched a project to build and use planning bills to forecast its needs for components. Planning bills are artificial groupings of components for planning purposes. They are used to simplify forecasting, master production scheduling (MPS), and material requirements planning. In particular, we refer to modular and super bills. Modular bills group subassemblies and parts based on whether they are unique to one specific product option or common to all product configurations. The super bill is a single-level bill of material in which the parent is a pseudo (not a real) product, called an average product, and the children are the modular bills. Finn-Power Italia managers developed modular and super bills using a well-known procedure (Orlicky 1975). It consists of identifying and grouping the option-related and common items (modular bill generation), and codifying the average product and associating it with the modular bills (super bill generation). To use super and modular bills, salespeople periodically made forecasts based on historical data and estimated the percentage use for each option, indicating the probability of each modular bill being used. The manufacturing planning-and-control system then used the super and modular bills to plan purchasing and production orders. By adopting planning bills, Finn-Power Italia was able to

—reduce the number of items requiring demand estimates, by shifting its focus from forecasting many end-product configurations to forecasting a few aggregate product or item groups; and

—introduce a two-level MPS structure, first stating the volume and timing of the average product (level one) and then those of its single-level child-codes (level two), instead of determining the end-product configurations to make.

By using planning bills, Finn-Power Italia expected to improve forecast accuracy, to formalize and simplify the links between forecasting, planning, and purchasing activities, and, consequently, to increase on-time deliveries. Although it adopted planning bills, Finn-Power Italia did not obtain the expected benefits, largely because it had difficulty updating the planning bills. The frequent product changes introduced by designers or requested by salespeople and the misunderstanding of their impact made updating planning bills complicated and harmed Finn-Power Italia performances.

Example

When sales required new options to meet customers’ needs or engineering changed a product to improve its performance, designers identified the components to be added or modified and filled in a document with a detailed description of the proposed product change and the codes for the substituted and new components. The resulting report was hard to read and incomplete; it did not provide salespeople, planners, and buyers with all the information they needed to align their plans and activities. In particular, it did not clarify the impact of the product change on the product options. For example, when the designers decided to modify the machine’s movable roll table—made up of a table frame and a movable plane—salespeople and production planners did not understand the impact the engineering change had on saleable product options. The roll table is a sort of table on which the automated bending machine places the bent sheets. Salespeople gave customers a choice of two options: a fixed roll table (a table frame and a fixed plane) or a movable roll table. In
the latter case, the movable-plane component makes it possible to transfer the bent sheets to the following work center. Before the engineering change, the firm used the same table-frame component for both roll tables, but once designers changed the movable component, it was not clear whether it could use the same table-frame component for both. Designers did not check this because they did not think about options and were unaware of the fixed-roll-table option. On the other hand, production planners and salespeople did not have the technical competence to resolve the matter, and the planners did not update the planning bills correctly. As a result, buyers bought only one type of table frame (the modified one) but continued to buy the old fixed plane, which would not work with the modified table frame. When, over the next few months, salespeople sold machines with the fixed-roll-table option, they set delivery dates based on their belief that the fixed roll table was still available. Only later, when designers produced the bill of materials, did the salespeople and production planners realize that the old fixed plane would not fit the new table frame. Thus, the firm had to buy new fixed planes and failed to meet the promised delivery dates. Unfortunately, the old fixed plane could not be reworked and had to be scrapped.

Because planners and salespeople did not understand the impact of product changes on modular bills and product options, the firm failed to fill customers’ orders on time and increased its stock of obsolete components and subassemblies. In several other instances, the firm had to spend time reworking components or subassemblies in stock to supply ordered components (Table 1).

<table>
<thead>
<tr>
<th>Performance indicators</th>
<th>Definition</th>
<th>1999 (%)</th>
<th>2002 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery punctuality</td>
<td>Machines delivered on time of the total delivered (in one year)</td>
<td>38</td>
<td>80</td>
</tr>
<tr>
<td>Time losses for rework</td>
<td>Time spent modifying components or subassemblies in stock as a percentage of annual assembly hours</td>
<td>9.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Value of obsolete stock</td>
<td>Value of components and subassemblies in stock that have become obsolete in one year, as a percentage of annual purchased material</td>
<td>3.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Table 1: The performance metrics for 1999 (before the implementation of the method) and for 2002 (after its implementation) show improvements.

The New Method

Finn-Power Italia’s experience demonstrates that the difficulty of updating planning bills limits their effective adoption for products characterized by high variety and frequent changes. By integrating planning bills with the concept of product modularity, we developed and implemented a method that made it possible for Finn-Power Italia to overcome this problem.

We developed our new method in two steps:

1. We identified the existing match between options, modular bills, components, and modules to support a structured exchange of information on product changes among engineering, production planning, and sales; and

2. We adapted this method by including the modules in modular bills with the aim of circumscribing the impact of product changes on modular bills.

We believe that we can improve people’s understanding of the impact of product changes on product structure by simultaneously considering the match between product components and modular bills (as planners do in preparing traditional planning bills) and between product components and the modules constituting the end product. Modules are separable physical subsystems of a product. They can be designed independently, but they still function together as an integrated whole. Designers usually decouple the interfaces between modules, that is, they change one module without requiring a change to the other modules for the overall product to work correctly. Ulrich (1995) and Baldwin and Clark (2000) discuss the theory of product modularity in detail, and Whitney (1993) discusses its usefulness in high-variety products. Designers always incorporated each product component in the modules. Similarly, planners incorporated each product component in well-defined modular bills. Because each modular bill is associated with a well-defined product option, it is possible to find a match among modules, components, modular bills, and options (Figure 1).

Implementation

As a first step in developing the method, we formed a team with engineering and production-planning
personnel and set out to accurately identify the product modules and the physical components they include.

(1) We identified the functional elements, that is, the individual operations and transformations that contribute to the overall performance of the product and the physical components of the product that perform those operations (Ulrich 1995) (Figure 2).

(2) We specified the interfaces among physical components and described in detail how those components interact, that is, how they fit together, connect, and communicate (Baldwin and Clark 2000).

Our module identification was facilitated by the fact that designers used to work in independent teams, each responsible for designing specific parts of the machine, decoupled from the others.

We also redefined modular bills. Although modular bills already existed before we implemented our method, we had to update them. To do so, we used an application program included in the Finn-Power Italia manufacturing-planning-and-control system that could compare two or more product bills of material and highlight shared and unshared components. In addition, we analyzed documents on sales orders salespeople had filled in to understand the full range of options Finn-Power Italia offered.

We initially analyzed modules and modular bills for the express bending cell EB 2550 mm family, which includes bending machines capable of bending sheets of up to 2,550 millimeters. We later extended our analysis to the other product families. We codified the product modules and modular bills and entered the codes in the company manufacturing planning and control system. We linked each code to a bill of material listing the components in the module or in the modular bill.
The functional elements of a product are the individual operations of the product that contribute to its overall function. Module A, which includes four physical components, performs the sheet loading. The sucker group takes the sheet and sets it within the bending machine by moving the sheet along the loading frame. Engines 1 and 2 are respectively responsible for horizontal and vertical transfers of the sheet. The interfaces among the four components are coupled because a change in one component would require a change in the other ones. Instead, the interface between module A and the other modules is decoupled because designers can change module A without modifying the other modules.

We spent a lot of time identifying modules, updating modular bills, and entering codes in the manufacturing planning and control system. We identified more than 100 product modules and 64 modular bills. We finished the work around September 2000. Since then, everyone in Finn-Power Italia with access to the manufacturing-planning-and-control system has been able to use the explosion and implosion queries to identify the components in a product module or a modular bill (through module/modular bill explosion) or to determine what modules and modular bills include a component (through component implosion) (Figure 3).

The old practice did not allow the identification of the modules to redesign (Figure 3) as the implosion resulted in parent codes which were often not physical modules.

Everyone can use queries at any time to fill in or interpret the document used to communicate product changes. To provide information about product changes, designers began using Excel files to provide a little essential information on (1) the initiators of the product change (usually salespeople or designers), (2) the types of changes (engineering change or new or modified option), (3) the impact of the product change on options or components, (4) the estimated end date for redesigning activities (only for product changes required by salespeople), and (5) the priority of the product change. They sent the documents out by e-mail to the sales, production-planning, and engineering functions.

Planners use the modular bill codes in Finn-Power Italia’s manufacturing-planning-and-control system to build super bills. Every month, salespeople estimate the percentage usage (PU) coefficients of all the options and the sales volumes of the bending machines. The time horizon is six months and the time bucket is the month. Based on their estimates, planners modify the super bills (Figure 4) by updating the percentage usage coefficients and calculate the MPS orders for the average product (Orlicky 1975). Thus, in material requirements planning (MRP),
logic, Finn-Power Italia’s manufacturing-planning-and-control system calculates plans for component requirements that buyers use in purchasing product components. The MRP program suggests purchase-order amounts that take into account the safety stocks (SS) associated with the modular bills, which are required to compensate for forecast errors.

Adapting the Method
At the end of 2000 and in 2001, some problems emerged that caused us to adapt the method to make it more robust to product changes. In particular, Finn-Power Italia redefined several technical characteristics of the bending machine, to improve the quality of bent sheet steel. After it made these changes, we had to include some parts that had been common to all product configurations in modular bills for specific options. When many common components become option related, we may have to regenerate the planning bills (Figure 5).

At Finn-Power Italia, designers all too often introduced changes whose scope or nature meant redefining the planning bills. At the end of 2001, we found that planners were spending a lot of time updating the relationships between modules, components, and modular bills and options. The continual updating and restructuring made production planners reluctant to use planning bills. Furthermore, because creating planning bills is time consuming, planning bills were often outdated, which caused production planning and procurement to lose money and damaged operational performance (Table 1). Thus, in 2002 we refined our method to make planning bills more robust to product modifications. We realized that modular bills included components or groups of components whose interfaces were coupled with other components in different modular bills, that is, they included partial modules, with some components of a given module included in a common-item modular bill, and others in an option-related modular bill. We modified modular bills to contain only whole modules, not simply product components, to limit the effect of product modifications on planning bills (Figure 6).

With modular bills containing only modules, planning bills retained the advantages of traditional planning bills and did not require frequent regeneration. The new planning bills differ from conventional ones in that components constituting a given module can never be split between the common items and an option-related modular bill. It can happen that planners include some common components in the option-related modular bills (Figure 6). Thus, safety stock of these components increases in the short term because
Modular bills before product change (old method)

- Modular bill common item code M7850
  - Table frame code 4999
  - Component A code 6534
  - Component B code 6751
  - Modular bill fixed roll table code M7955
    - Fixed plane code 8434
  - Modular bill movable roll table code M7777
    - Movable plane code 4957

Modular bills after product change (old method)

- Modular bill common item code M7851 (changed)
  - Component A code 6534
  - Component B code 6751
  - Modular bill fixed roll table code M7956 (changed)
    - Fixed plane code 8434
    - Table frame code 4999
  - Modular bill movable roll table code M7778 (changed)
    - Movable plane code 4958 (changed)
    - Table frame code 5000 (changed)

Figure 5: In this simplified real case of modular bill regeneration, the bending machine has two options: fixed roll table and movable roll table, and two associated modular bills (codes M7955 and M7777, respectively). The roll table is a sort of table on which the automated bending machine places the bent sheets. If it is movable, it includes the movable-plane component that makes it possible to transfer the bent sheets to the following work center. A modification of the movable roll table (which consists of a movable plane and a table frame) may require redesign of some components of the modular bill that contains common items, for example, the table frame code 4999. Thus, the table frame becomes option related. As a result, we would produce three new modular bills, code M7851, code M7956, and code M7778.

planners do not plan them as common items (Figure 4). If designers change the product frequently, and the cost of the component that is no longer included in the common parts, for example, the cost of the table frame (Figure 6), is not critical, using our approach to create planning bills is advantageous.

Updating the modular bills by entering the parent-child relationships between modules and modular bills took a few weeks. Adapting the method did not affect planners’ use of modules and modular bills; they continued to use them to plan component requirements and support personnel in managing product changes.

Comparing the Old Method to the New Method

The old method and the new method differ mainly in the data input and output and application limits (Table 2).

Unlike the old method, the new method requires creating, codifying, and entering product modules in
Modular bills before product change
(new method)

Modular bill fixed roll table
code M6782

Module fixed roll table
code G4832

Fixed plane
code 8434

Table frame
code 4999

Modular bill movable roll table
code M6843

Module movable roll table
code G4933

Movable plane
code 4957

Table frame
code 4999

Modular bills after product change
(new method)

Modular bill fixed roll table
code M6782

Module fixed roll table
code G4832

Fixed plane
code 8434

Table frame
code 4999

Modular bill movable roll table
code M6844 (changed)

Module movable roll table
code G4934 (changed)

Movable plane
code 4958 (changed)

Table frame
code 5000 (changed)

Figure 6: The main characteristic of the new method is that modular bills contain whole modules. This makes it possible to limit the effect of product modifications on planning bills. On the left, the modular bill fixed roll table contains the whole module fixed roll table, which consists of a fixed plane component and a table frame component. Similarly, the modular bill movable roll table contains the whole module movable roll table and its components. The impact of a modification to the movable roll table is limited to the module movable roll table and its components, thus planners must generate only a modular bill. In fact, on the right, after this product change, the modular bill fixed roll table (code M6782) and its content and codes remain unchanged, whereas planners must generate new codes for the modular bill movable roll table, the module movable roll table, and its components.

the manufacturing-planning-and-control system. Furthermore, the new method as updated in 2002 differs from the initial version in that the modular bills now include whole modules rather than components.

The output of the new method includes detailed component-requirement plans, as did the output of the traditional method, and it also helps the personnel who update the planning bills to understand the impact of product changes on product structure. The adapted version of the new method improves the robustness of planning bills as products change.

Barriers to Implementation

To develop and implement our method, we faced no particular technical obstacles. We used existing applications and systems in the Finn-Power Italia’s manufacturing-planning-and-control system, such as the bill-of-material-comparison routine, explosion and implosion queries, and the material-requirements-planning system.

However, we had to overcome organizational hurdles to gain the acceptance of senior managers and planners. The fact that one of the authors has worked since 2000 as planner for Finn-Power Italia and that the company has a long history of collaboration with the University of Padova contributed to improving the openness and trust towards the two researchers.

Each year, senior managers, including Finn-Power Group’s chief financial officer, required us to justify
Data input | Data output | Limitations
---|---|---
Old method | Traditional planning bills | Component requirement plans | Difficulty of correctly updating the planning bills
| Modular bills (including components) | | Lack of robustness of planning bills to product changes
| Super bills (percentage usage coefficients and safety stocks) | | 
| Average product volumes | | 

New method (Step 1) | Traditional planning bills | Component requirement plans | Lack of robustness of planning bills to product changes
| Modular bills (including components) | Explosion/implosion reports on the relationships between components, modules, and modular bills |
| Super bills (percentage usage coefficients and safety stocks) | | 
| Average product volumes | | 
| Product modules | | 

New method (Step 2) | New planning bills | Component requirement plans | Increased stocks of components no longer included in the common-item modular bill
| Modular bills (including modules) | Explosion/implosion reports on the relationships between components, modules, and modular bills |
| Super bills (percentage usage coefficients and safety stocks) | | 
| Average product volumes | | 
| Product modules | | 

Table 2: Finn-Power Italia’s old method and the new method of generating and using planning bills differ. In the new method, we considered both the initial version (Step 1: formalizing the match among options, modular bills, components, and modules) and the following adaptation (Step 2: generating new modular bills containing whole modules). The main difference between the old method and the initial version of the new method is the identification and codification of the relationships between product modules and components in modular bills. Both approaches require planners to spend a lot of time updating and restructuring planning bills, especially when product changes are frequent. The new method as updated in 2002 overcomes this limitation, because modular bills include whole modules. This makes it possible to limit the effect of product modifications on planning bills. The new method helps planners to plan detailed component requirements and also to understand the impact of product modifications on planning bill structure.

Results and Conclusions
Assessing the benefits of our method was difficult. We had to find the data to measure company performance (Appendix). We compared three performance indicators for 1999 and for 2002.

The new method increased on-time deliveries by 52.5 percent, reduced time lost to reworking by 54.3 percent and reduced the value of obsolete stock by 62.5 percent. By changing the way it developed

continuing the research effort. They monitored our progress and required us to document the details of our research. In particular, at the beginning of 2001, when planners complained that updating planning bills took too much time, we actively championed the project with senior managers. We maintained an open and honest dialogue with them about our progress and took every opportunity to demonstrate the payoff to the company, painting a picture of the system’s possible uses and impact.

We also faced resistance from planners. From the project’s outset, we sought the participation of planners, designers, and salespeople. Understandably, at the end of 2000 when Finn-Power Italia changed several technical characteristics of its bending machine, planners saw our proposed method as a threat. Product changes meant updating planning bills. Planners had to read the documents reporting product changes and update the option-related or common-item modular bills, manually entering data into the manufacturing-planning-and-control system. For several months, product changes were frequent, and planners were spending 16 hours a week updating planning bills. We tried to gradually earn their support in reviewing our method. We agreed to build and use modular bills that included whole modules, thus limiting the time spent updating, despite the risk of increasing inventories. We fortunately gained the active participation of the operations manager, who convinced planners that the adjusted method would facilitate their work. Planners now universally view the new method as a useful planning tool.
and used planning bills, Finn-Power Italia overcame the limits of traditional planning bills.

While planning bills are widely recognized as suitable planning tools for high-variety products, they are ineffective when frequent product changes and complex product structures complicate planning. Our method resolves

— the difficulty of updating planning bills, and
— their lack of robustness to product changes,
thus helping Finn-Power Italia to improve its performance.

We are pleased to have had the opportunity to develop and apply what Finn-Power Italia considers a very important decision-support method to

— identify options or subassemblies and components affected by product changes, and
— manage planning and purchasing activities.

We expect to use our knowledge and apply our method in managing other activities, such as determining production costs of modules and modular bills and options. Workers currently record the time spent assembling each machine in the manufacturing-planning-and-control system. Based on this data and material costs, the system calculates the final production cost of each machine. We intend to modify the way the system manages such data by including each modular bill and module as phantom codes in the final bill of material for each product. Workers would record the time spent assembling modules, and the system could then calculate the cost of each module or modular bill and option, thus making it possible to isolate its contribution to the cost of the finished product.

Appendix. Performance Metrics

Finn-Power Italia’s performance metrics concern on-time deliveries, time lost reworking parts, and the value of obsolete stock.

To determine delivery punctuality, we considered the number of machines delivered on time out of the total delivered in the year. We obtained the data we needed, the promised delivery date and the actual delivery date, from records on the machines to be delivered each week and their actual delivery dates. We analyzed the records on bending machines to be delivered in 1999 and 2002 and calculated delivery punctuality for these two years.

To determine time lost on rework, we considered the time spent on modifying components and subassemblies in stock in one year as a percentage of the annual assembly hours. When a component has to be modified or reworked, production planners create a “modification job” in the manufacturing-planning-and-control system by entering the code of the component to be changed, its production cycle, and some notes including the reason for the rework. When workers complete the modification, they record the number of hours spent modifying the components in the manufacturing-planning-and-control system. By analyzing the documents concerning rework in 1999 and 2002, we calculated the hours spent on rework in one year. In the manufacturing-planning-and-control system, workers also enter the number of hours spent assembling each machine, which enabled us to calculate annual assembly hours.

We calculated the value of obsolete stock by determining the value of the components and subassemblies in stock that became obsolete in one year as a percentage of the annual value of purchased materials based on data in the manufacturing-planning-and-control system.

References


Ing. Alberto Longobardi, Operations Manager, Finn-Power Italia S.r.l., Viale Finlandia 2, 37044, Cologn Veneta, Verona, Italy, writes: “I am writing on behalf of Finn-Power Italia to confirm the application of the methodology that leverages planning bills and product modularity to align Sales, Production Planning and Engineering contrasting goals. As an Operations Manager of Finn-Power Italia I was in direct contact with Pamela Danese and Pietro Romano to determine the needs and to face the problems of the development and implementation of the method-
ology. I worked most closely with Pamela Danese, who performed the work in Finn-Power as part of her doctoral dissertation.

“While part of the data is masked for privacy reasons, the general information on what occurred in the project and the results are accurate. I found their work very useful. We have used it and will continue to use it as an important tool for our designing, selling, and planning activities. As a matter of fact, I was very impressed that the study was both scientific and practical. The project began in January 2000 and was completed in March 2002, although this successful cooperation is still in place, and—I hope—will continue in the future.”