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PROCESS SIMULATION AS A TOOL FOR ACTIVITY-BASED COST MANAGEMENT

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ABSTRACT

As an alternative to the traditional cost-allocation method of accounting, activity-based costing is gaining popularity as a management tool for making informed strategic decisions. This paper illustrates the benefits of activity-based management and presents an example of how activity-based costing concepts were integrated into a model of a composite assembly shop. The model demonstrates how analyzing production processes to gain an understanding of resource and activity relationships improves cost driver visibility. Adding the distinction between value-added and non-value-added tasks to the activity analysis will lead to improved decision-making capabilities.

1 INTRODUCTION

Despite the use of traditional absorption-based accounting methods at the company level, activity-based cost management (ABCM) techniques can be effectively used at lower levels to gain insight into the total costs of manufacturing. By taking an ABCM view of the production environment, a process simulation model can be a valuable tool when analyzing an area for potential improvement.

Traditional accounting systems were designed during a period of time when manufacturing was labor intensive, there was little emphasis on product cycle time, and overhead costs were only a small percentage of the total product cost. Today's automated environment has resulted in higher overhead costs with direct labor comprising as little as five percent of the total costs. Competitive environments have also turned attention to the need for shorter and shorter manufacturing cycle times. The ever-increasing portion of cost that is overhead becomes the "hidden factory" and becomes more and more difficult to address (Chen 1996). The goal of activity-based costing (ABC) is to identify the relationship of costs to activities and treat as many of the costs as possible as variable. In that way, the "hidden factory" becomes visible.

ABCM is an approach to management that is specifically focused on providing the information needed to improve business processes. It is a management technique that uses ABC as a tool, but it is more than an accounting system. The ABCM system provides information on opportunities for improvement based on the true cost drivers of an organization. It also focuses on providing performance metrics that monitor progress, ensuring that once improvements have been made they are being sustained (Clarke and Bellis-Jones 1966).

1.1 Activity-Based Cost Management

Although ABC is just another accounting system, it differs from other accounting methods in that it focuses on activities rather than the costs. Similarly, the system of ABCM aims at controlling the activities, thereby controlling costs. ABCM is a control system that focuses on doing the right things and doing them well. It directs attention to process value, then utilizes ABC for process and product costing and performance measurement. ABCM begins by looking at all of the activities involved in a work package and separating them into value-added and non-value-added categories (McCormick 1992). This is an important step in truly understanding the cost of a product and making informed decisions. If resources are being consumed, costs are increasing. If a value-added activity is being performed, costs are increasing but so is the value of the product. With a non-value-added activity, however, costs increase but the value of the product does not. Identifying, reporting and controlling non-value-added activities is an important aspect of ABCM.

Proponents of ABCM claim that it will shed light on the true cost of products and help management make better decisions with this improved cost picture. The ABC accounting model can provide a more detailed look at how resources are consumed in a production process. When operating costs are allocated to the products according to resource usage, the profit margin of a product can look surprisingly different. A product that requires only a small number of direct labor hours to manufacture will only get a small portion of the overhead costs applied to it with the traditional absorption-based method of accounting. If, however, the product actually requires a large number of resources to support its production, the ABC method of allocating costs based on resource utilization and cost driver information will show the product to be costly and will highlight the fact that the profit margin may not be as large as originally thought.

Opponents of ABC feel that it is expensive to implement, and it just shuffles the costs of doing business from one category to another rather than improving them. Skeptics of ABC point out that in most cases, market conditions and the demand for products determine the selling price, so that allocating costs at such low levels of detail does not necessarily improve decision-making. In addition, there is some justification for considering all costs except materials as fixed. Most companies do not send their employees home if there is temporarily no work for them. Most companies recognize the value of their work force and retain all personnel through periods of slight slowdown. They have to work on rush jobs during busy times and other times they work a little slowly because there are not many tasks to do. But the employees, as well as their supervision, will most likely be there and be paid for 40 hours per week despite irregular work loads. Similarly, plant maintenance, utilities, and machine maintenance are other examples of costs that must be incurred, independent of how many units of what products are being manufactured (Doost 1997).

1.2 Activity-Based Costing

Traditional costing methods, such as absorption-based costing, track only the direct labor hours or machine hours and material costs for each product. These cost elements form the allocation base for distributing the remaining costs associated with all other aspects of production. With absorption-based costing, these operating costs, or overhead items, are distributed across each product, according to some formula based on a percentage of direct hours or material dollars. Support organizations, such as Industrial Engineering, Design, Quality Assurance, or Procurement, as well as facilities items such as electricity, water and rent are priced as a factor applied to the touch labor hours.

With ABC, the actions that take place are first categorized into activities. Some examples of activities are “purchase raw material,” “machine part A,” or “write production planning.” Resources, items that are used or consumed in the performance of an activity, are then identified. With an ABC system, costs are collected and reported against the activities. To accomplish this cost collection, a primary cost driver is selected for each activity (No and Kleiner 1997). A cost driver is an item that has a direct relationship to the consumption of resources. For example, in the Procurement environment, one activity would be “buy raw materials.” The resource would be the labor hours of the Buyers. The primary cost driver for the activity of buying raw material might be the number of purchase orders placed. A direct relationship can be drawn between the number of orders placed and the number of Buyer resources spent on this activity. If the cost of procuring raw materials is $50,000 per year, and 500 purchase orders were placed, the cost per purchase order would be $100.

The cost of Procurement can now be treated as a variable cost for a product. Since a relationship has been identified between placing a purchase order and the cost of a Buyer, by tracking the number of purchase orders placed for a given product line the cost of Procurement can be allocated according to actual usage of the department, rather than as an arbitrary percentage. By setting up a system of activities, resources and cost drivers, many of the cost components typically considered to be overhead can be attributed to the product as a function of usage rather than as a proportion of direct labor.

1.3 ABC and Simulation

Simulation modeling is a useful tool for emphasizing the concepts of ABCM. The elements of a model are direct parallels to the elements of ABC. In a simulation model, it is necessary to define the activities that occur in the system, determine the resources required to perform each activity, and decide what variables or factors are important measures of performance. Because of the use of traditional, absorption-based methods of cost collection, however, the tendency when creating and analyzing a model of a manufacturing area is to focus on the utilization of direct touch labor resources and the total cycle time of the product. Also, in a typical manufacturing company, the largest amount of information exists regarding the direct touch labor element of the cost.

Since Arena® can easily track a large number of variables and attributes, it is an easy matter to accumulate costs by category and track the number of occurrences of cost driver items. By keeping the ABCM objectives in mind while constructing the model, performance measures can be selected that help assess the value of processes. For example, in a manufacturing facility that uses absorption-based accounting, items like the cost of travel between work areas, the cost of inspections, or the cost of documents like quality discrepancy reports, are lost in overhead accounts. By tracking the number of moves between work centers, the amount of time a part spends in inspection, or the number of inspection rejections that occur, a different picture of costs can be presented by the simulation model. Maintaining an ABCM approach in the model can highlight areas for improvement that are not readily apparent from the traditional accounting information.

The ABCM system of controlling activities was used as a guide when creating a model of an antenna subassembly shop at the Boeing facility in Mesa, Arizona. The processes included in the model, the modeling approach used, and the results of the study are presented here.

2 SYSTEM DESCRIPTION

The Boeing-Mesa facility is primarily an assembly shop for the Longbow Apache helicopter, but the company also has the capability to fabricate sheet metal and metallic components, wire harnesses, and composite parts. Also, there is capacity for painting, chemical processing, and several types of test and inspection. In addition to fabrication and assembly for the Longbow Apache Program, Boeing-Mesa also produces a large number of subassemblies that ship to other Boeing components for use in a variety of end items, both military and commercial.

The model presented in this paper addresses two composite subassemblies that are produced in Mesa for shipment to Boeing - St. Louis. The subassemblies, an antenna receiver and transmitter, are comprised of several detail parts that are either fabricated in the composite shop or procured from vendors. Figure 1 shows the basic components of the antenna assemblies.

Prior to beginning production of the new antennas, a short development program was conducted where six shipsets of components were fabricated to validate the production processes and the antenna performance. This prototype effort took place in a small development shop, located in a different building than the production shop. Before moving the fabrication of the composite subassemblies into production, a simulation model was requested to assist with the transition. The model was to serve several purposes. First, a planning tool was needed to evaluate the initial resource requirements, the tooling needs, cycle time and work-in-process inventory levels. As a second goal, the model was to assist with planning the resource requirements to increase production rates from the initial rate of one shipset per month to the projected maximum rate of three shipsets plus spares per month. The third objective of the model was to provide a baseline tool that could be used to identify and evaluate proposed improvement projects.

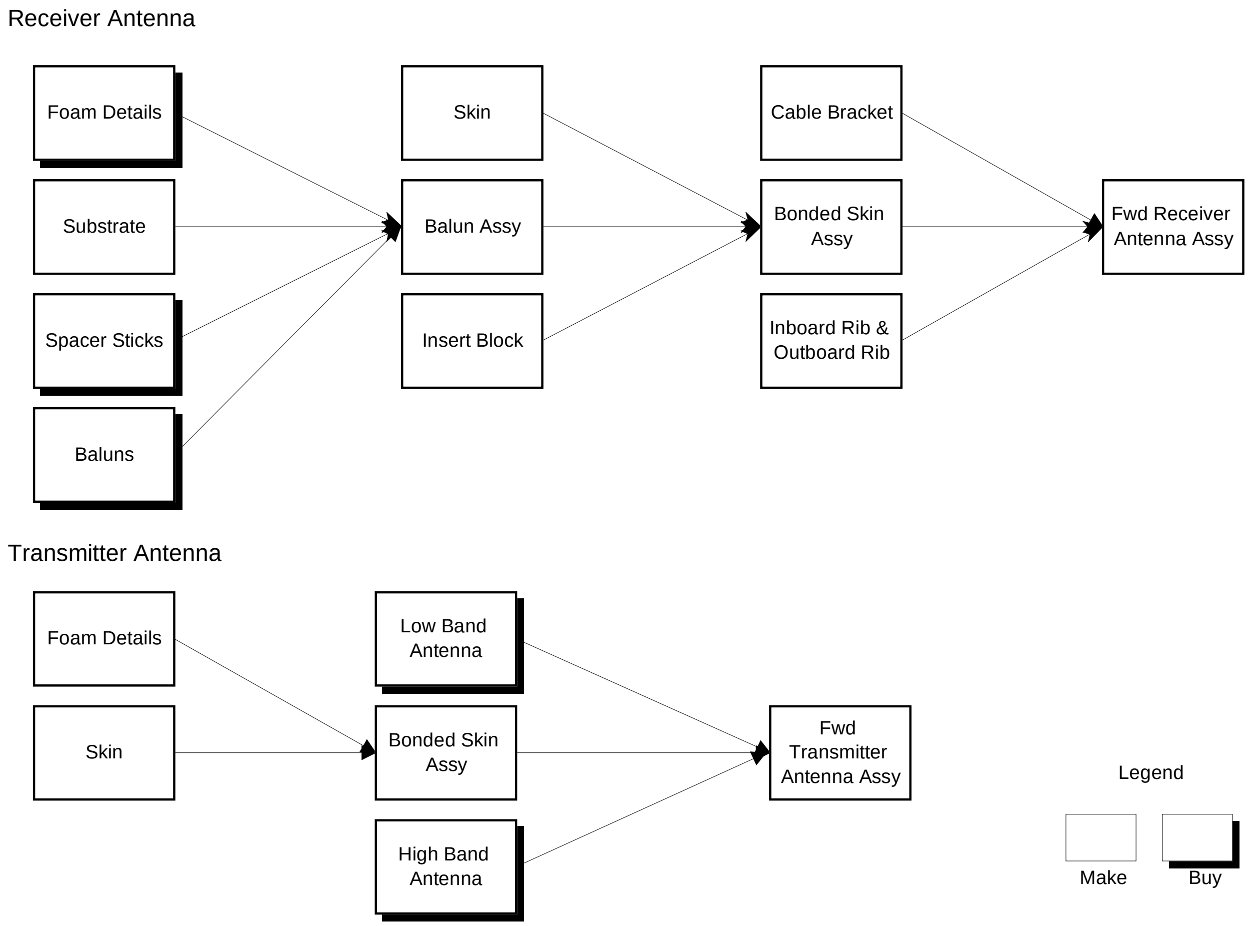

Figure 1: Major Subassembly Components

2.1 Activity Centers

There are three primary processing centers in the composite shop that the fabricated components of the antenna subassemblies travel through: the lay-up area, the cure area and the assembly/trim shop. These three areas were the focus of the simulation model. The antennas also travel to test cells and to the paint shop, and two of the receiver antenna components travel to a subcontractor for additional processing and testing. For the purposes of this model, these areas were considered as outside processing and were not modeled in detail. The number of parts out to any of these processing areas and the amount of time spent were the only data items tracked.

The lay-up area is a clean room environment. All ply cutting activities, ply lay-up, vacuum debulking and bonding tasks are performed in this area. Many components for a variety of Boeing products are processed in the lay-up area and many of the resources are shared. The decision was made, however, to dedicate a section of the clean room to the antenna program so that only the manpower would be a shared resource. For the start-up efforts, there would be eight lay-up technicians assigned with only a single shift operating.

The cure area contains both the autoclaves and ovens that are used for curing the various products of the composite shop. The total capacity in the cure area is three autoclaves and four ovens. These resources are shared by all programs traveling through the Boeing - Mesa composite facility. Since the production rates for the antennas are so low, only a portion of each resource is required. To simplify the modeling of these shared resources, therefore, the model was created with a capacity of one autoclave and one oven. The ovens are not highly utilized, so this simplification did not present a problem. There are a number of small and medium sized ovens in the composite shop and there is rarely a wait to access one. With the autoclaves, however, it was necessary to add a delay representing the potential wait for an autoclave to become available. The percentage utilization was tracked to determine how much of the capacity would be required for the antenna program. The cure area is the only area operational on a three-shift basis.

All of the non-clean room composite tasks, such as trimming, drilling, and installing hardware, are done in the assembly/trim area. Most of the work done in this work center is performed on work benches with dedicated tools. The volume of assembly/trim work on the antennas is low, therefore only one technician will be assigned for the start-up production rate. Like the lay-up area, the assembly/trim shop is manned only on one shift.

The assembly process for the antennas include trips to non-destructive testing (NDT), paint, a radar testing range, a silk screening shop, and two different vendors. These areas were not modeled in detail for two reasons. First, the primary focus of the model was the composite processing area. None of these other areas are related to the composite shop except as a supplier or customer of composite products. The only information of consequence is the length of time that the components are out of the area for processing. Secondly, many different parts from a variety of different programs are processed in the paint shop and NDT. It would be a difficult task to include all of these competing entities in the model. To simplify the model, the cycle time for the trip to each of these shops was used as the lowest level of detail.

2.2 Production Requirements

The initial production rate for the antenna is 15 shipsets in an 18 month period. The rate ramps gradually to a maximum of three shipsets per month. All of the components, except the foam details and the substrate for the receiver antenna, will be produced in lot sizes of one. The foam details and substrate are the two components that go to an outside vendor for processing. Both vendors have elected to process the parts in 10 piece lots. The foam details, therefore, will arrive to Boeing - Mesa in 10 piece shipments. Once arriving to Mesa, however, the foam details will be processed in single unit lots. The substrate is fabricated in Mesa and then shipped to a vendor for etching. This component will be fabricated then shipped to the vendor in 10 piece lots. After returning to Mesa from the etching operation, the substrate will be handled in single piece lots.

After the substrate, foam details, spacer sticks, and baluns are integrated into the balun assembly, this subassembly goes out a vendor for additional processing and testing. This will again require shipping in a batch size of 10. Similar to what occurs with the detailed parts, when the subassemblies return to Mesa from the vendor, they will once again be processed in single piece lots due to tooling constraints and production schedules.

2.3 Model Scope

The focus of this model is the composite shop. As mentioned previously, areas such as NDT, paint, and the silk-screen shop are in the model only at a high level. Data was collected on the cycle time involved with sending a part to these areas, and that cycle time was used as the station processing time in the model. To some degree, this inflates the statistics for the amount of value-added processing time because it is not known how much of that cycle time is actually spent in non value-added tasks. It was decided, however, to maintain this level of detail for the antenna model and expand on this information in a separate model if required at a later date. In keeping with the focus on the composite processes, it was decided that the metallic parts that only arrived to the composite shop for assembly into the antennas would be treated the same as purchased parts. They are essential for assembly, but their processes are not considered within the scope of this model. The insert block and the cable bracket in the receiver assembly are the only in-house make items that fall into this category.

3 MODELING APPROACH

Even though the Boeing Company does not use ABC for its accounting system, it was decided to take the ABCM approach to cost analysis with the antenna shop model. The typical resource utilization, cycle time, and inventory level statistics were collected to help with the production planning objective. But since the model would be used in the future to assist with reducing costs and evaluating improvement candidates, it was decided that the value analysis of activities and the cost driver information would be a useful focus. The major activities that occur in the production of the antennas were selected and an attribute was assigned to collect the amount of time an entity spent in each of the various activities. The activities were then designated as either value-added or non-value added.

3.1 Activity Selection

In the interest of providing the most useful information related to the antenna fabrication process, some liberty was taken in the identification of the activities for cost collection. Since cycle time of the parts was an item of interest in the study and an important performance metric, waiting times that did not necessarily involve labor costs were segregated from the labor portion. In the lay-up area, for example, costs for performing the tasks were separated from the time spent waiting for a lay-up technician. Although waiting for a resource it not an activity per se, it is an element of the cost that would assist management with decision-making. Waiting times for each of the major resource types as well as other categories of waiting time were included in the cost breakdown.

The major categories selected for tracking are as follows:

- Value-added
  - Lay-up
  - Assembly/Trim
  - Cure
  - Machining
  - Inspection/Test
  - Other Processing
- Non Value-Added
  - Rework
  - Transportation/Shipping
  - Wait for Lay-up
  - Wait for Assembly/Trim
  - Wait for Cure
  - Wait for Inspection
  - Wait for Tool
  - Wait for Parts
  - Wait for Batch
  - Wait in MRB

The elements defined as value-added activities are those tasks that contribute to the product’s value to the customer. The categories that were defined for the antenna model represent the general work centers where the assembly tasks are performed. Areas previously defined as outside the focus or scope of the model, such as vendor processing, paint and silk screening, were combined into the category “Other Processing.”

The value-added activities were broken down even further in the simulation model. Most manufacturing processes can be separated into setup and run times. The setup time is actually a non-value-added segment of a value-added activity. Therefore, it would be desirable to be able to isolate the setup costs to determine their contribution to the costs of the program. Using the resource frequencies available in Arena, the setup portion of the tasks were tracked separately from the run time for the lay-up, assembly/trim, and cure area resources.

The non value-added activities tracked in the model primarily represent added cycle time to the process, but some of them also represent labor costs. The two activities requiring labor resources are rework and transportation/shipping. The transportation/shipping costs include both the movement of parts to outside vendors and the transportation of parts internal to the facility between work areas. The activities not requiring labor, but included because of their impact on cycle time include: the waiting times in each of the major work center resources; the time waiting for tools or parts; the time required to accumulate enough components to create a shipping batch; and, the time spent in the Material Review Board (MRB) waiting for a disposition on an inspection rejection. For this model, "Wait for Parts" is the time members of a subassembly spend waiting for the other members to be available for assembly. For example, the substrate on the receiver assembly is bonded to the foam details that are received from a vendor. If the foam details have not been received from the vendor when the substrate is ready, the bonding operation can not take place and the foam details are waiting for parts.

3.2 Cost Drivers

Cost drivers can be viewed as the items that directly relate to the level of costs. It is desirable to find a single cost driver for each activity. As discussed earlier, the primary cost driver associated with a procurement activity is most likely the number of purchase orders placed. With the scope for the antenna model set on the composite shop, there are not many cost drivers to consider. The primary driver for most of the activities is simply the number of direct labor hours required to build the part.

It was decided that capturing the costs outside the traditional accounting scheme for the antenna was also an important part of the analysis. With the absorption-based method of costing, many of the production costs are not readily apparent. Areas like Inspection and Production Control are generally estimated to be a factor of the direct labor hours and the actual costs are not collected or reported at a detailed level. There may, in fact, be several costs incurred with just the inspection process. First, there is the actual inspection itself. Then, depending on whether or not the part passes inspection, there could be a trip to MRB followed by some amount of rework. To help segregate the inspection costs in the model, two cost drivers were selected. First, the number of inspections should directly correlate to the cost of performing the inspection. The second cost driver relates to the costs associated with a nonconformance. When a part does not pass inspection, a Product Assurance Record (PAR) is created. This document moves with the part to MRB where the appropriate rework process is determined. Therefore, the number of PARs written is a good cost driver for the costs associated with nonconformances.

All of the waiting times experienced in the system result in excessive inventory and increased cycle time. Both of these items are undesirable from a business standpoint for several reasons. Excess inventory means that more money is invested in parts than necessary. Excess inventory also means that more floor space is needed to store the parts. Work-in-process is also susceptible to damage while it is on the shop floor waiting to be processed. Added cycle time to a manufacturing process means a less responsive system to changes in design, longer lead time for customer demands, and possibly more equipment. These costs, whether overhead items or intangible factors such as response time, are all directly related to the number of parts in the system. Therefore, the number of components in the system was selected as a cost driver element and performance metric for the system.

The last cost driver selected for the antenna model is the number of moves made by the part to different work areas. The activity of moving parts is done by Production Control personnel. Twice per day the Production Control representative takes the components from the completed work center to the next work center in the process. The number of moves, therefore, should directly correlate with the transportation costs for a product.

3.3 Output

The number of hours spent in each of the activity categories was tracked with an entity attribute in the antenna simulation. After the processing is complete, before each entity is disposed, the attribute values are tallied for both the transmitter and receiver. The values in each category are the sum of the times for all components in an assembly that move through the composite area. Therefore, the "Wait for Inspection" time for the receiver is the waiting time experienced on the substrate, balun assembly, skin, bonded skin assembly, ribs, and forward receiver assembly. Similarly, the time for the transmitter is the sum of the waiting time experienced by the foam details, skin, bonded skin assembly, and forward transmitter assembly.

Visual Basic for Applications (VBA) code was used to write the tally values to an Excel worksheet and create a chart of the results. Sample code from SMARTS files provided with Arena 3.0 was modified for this application. On the

RunEndReplication event of the model, the average value for each tally was written to an Excel worksheet. Then, prior to charting the results, the average over all the replications is calculated and added to the spreadsheet. This average over all the replications is the value used in the graphical output.

4 BENEFITS OF APPROACH

When all costs are defined as a percentage of direct labor costs, the tendency is to focus on reducing the number of direct labor hours required to make the product. By definition, all other costs are reduced since they are a proportion of direct labor costs. This is not always the case in practice, however. Reducing the labor costs generally does not result in a true reduction in the support costs. Unless supporting headcount is reduced, or inspection times are improved, or rework is eliminated, the actual cost in these support areas remains unchanged. The true effect is an increase in the allocation percentage that must be used.

4.1 Traditional View

A sample listing of some output statistics after 20 replications of the model is shown in Table 1. The simulation results discussed here are for a one year period of time at the maximum production rate of 3 shipsets per month. Figure 2 displays some of the Excel output generated by the model for the receiver assembly. Looking at the antenna model output with the goal of reducing labor, the first opportunity for improvement seems to be in the lay-up area. When considering the direct touch labor only, the lay-up area accounts for approximately 60% of the costs of the transmitter assembly and 26% of the receiver. Process improvements that reduce the time required to lay up antenna components could have a significant impact, especially on the transmitter. Additionally, the eight lay-up resources spend between 4.5% and 8.5% of their working time on setup tasks, which is sometimes as much as one third of the total time they spend on laying up parts.

It should be noted that the resource utilization of the lay-up technicians is very low. Clearly, there is no need for eight workers in this area. As mentioned earlier, the composite shop handles work for a variety of Boeing products. The workers in the lay-up area can move from one program or part to another as the work load requires. When there is no work on the antenna program, the resources can be used on other programs, in other work areas of the shop. The antennas have some complex components, and it was a management decision to ensure that at least eight technicians were trained early in the program to minimize risk. The statistics of interest, therefore, are the value-added and non-value-added times rather than the busy and idle times.

Another area that is high cost for the transmitter assembly is the outside processing. This category comprises over 50% of the direct touch labor costs. In order to see a reduction in cost for the transmitter, it would be prudent to look at the items in this category for potential improvements.

4.2 ABCM View

The ACBM approach to segregating costs provides a different view of the possibilities for improvement than the traditional approach of focusing on direct touch labor. The top-level Excel chart that combines all the categories from Figure 2 is not shown, but the heading provides the percentage of the total that is represented by the value-added and non-value-added activities. It can be seen that value-added activities account for only 13.3% of the total time a receiver assembly is in production. The charts also show that the test and inspection category of value-added activities is higher than any of the other processes.

When looking at the non-value-added portion of the receiver time, it is apparent that there should be some investigation into the amount of time a component spends waiting for parts. It could be that the multiple lot quantities for the foam details and the substrate are resulting in a wait for parts that will have to be tolerated as long as these larger lots are desired. It is possible, however, that some scheduling changes for the components will reduce the number of units waiting for parts. Another option that management might consider after seeing these results is to evaluate the effect of different lot sizes on the cycle time and negotiate a change with the vendors.

Figure 3 shows the same information for the transmitter assembly. It can be seen that the value-added segment of the transmitter assembly is only 33% of the total processing time. For both the receiver and transmitter, the cost of inspection is a significant percentage of the value-added time. With a traditional, allocation method of costing, both the assemblies would have the same percentage applied to the direct labor hours to allow for inspection. By looking at the actual costs, however, it is clear that the two assemblies do not utilize the same percentage of inspection resources. The receiver assembly has inspection comprising almost 40% of the value-added labor, but it is only 5% of the total cycle time (40% of 13.3%). Almost 50% of the value-added activities on the transmitter are a result of test and inspection, which is more than 16% of the total cycle time. A reduction in the inspection turn-around time, a move to operator verification, or sample inspections would all be worthy projects to improve performance on the antenna transmitter assembly.

Table 1: Sample Model Output

Output Summary for 10 Replications

OUTPUTS

Identifier	Average	Half-width	Minimum	Maximum	# Reps
Machine utilization	.84554	.00689	.83209	.86421	21
OutToAEL	5.4359	.04705	5.3561	5.5000	21
Number of Inspections	2402.8	4.9744	2392.0	2413.0	21
Number of Moves	8603.6	19.180	8562.0	8650.0	21
Number of PARs	61.272	5.5067	52.000	79.000	21
Avg Days In Sys Recvr	88.269	.84927	86.052	90.309	21
Avg Days In Sys Trans	33.827	.53167	32.880	35.884	21
Total left trans	35.727	.57818	34.000	37.000	21
Total right trans	35.636	.43095	35.000	37.000	21
Total left recvr	34.454	.33381	34.000	35.000	21
Total right recvr	34.454	.33381	34.000	35.000	21
Days Betw Rtrecvr	9.3562	.10912	9.0819	9.5775	21
Days Betw Rttrans	10.042	.10311	9.8199	10.282	21
Days Betw Lttrans	10.053	.12770	9.8506	10.516	21
Days Betw Ltrecvr	9.3618	.12161	9.1234	9.6592	21
Lexskin in System	2.1895	.10322	2.0120	2.5697	21
Lexcore in System	3.5895	.10322	3.4120	3.9697	21
Flapskin in System	9.6334	.07499	9.5324	9.9078	21
Flapcore in System	6.6334	.07499	6.5324	6.9078	21
Lexassy in System	5.6252	.05763	5.4962	5.7536	21
Flapassy in System	11.456	.13542	11.060	11.787	21
Ribs in System	15.788	.15038	15.243	16.086	21
Substrate in System	35.7526	.04031	35.6516	35.8444	21

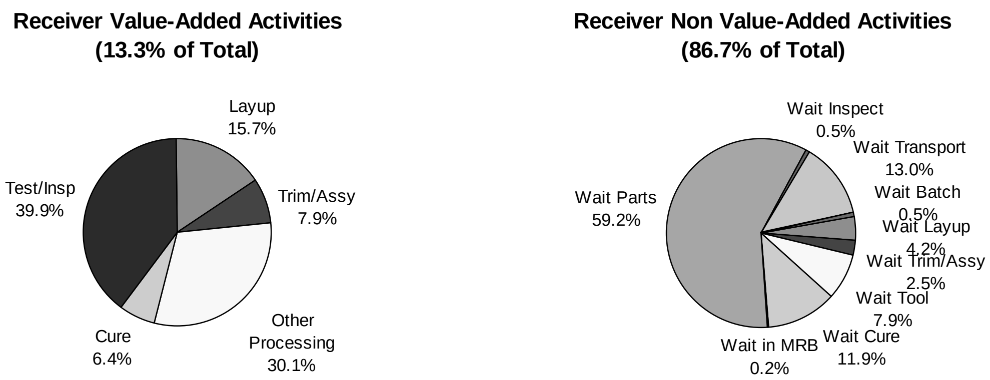

Figure 2: Value-Added and Non Value-Added Receiver Activities

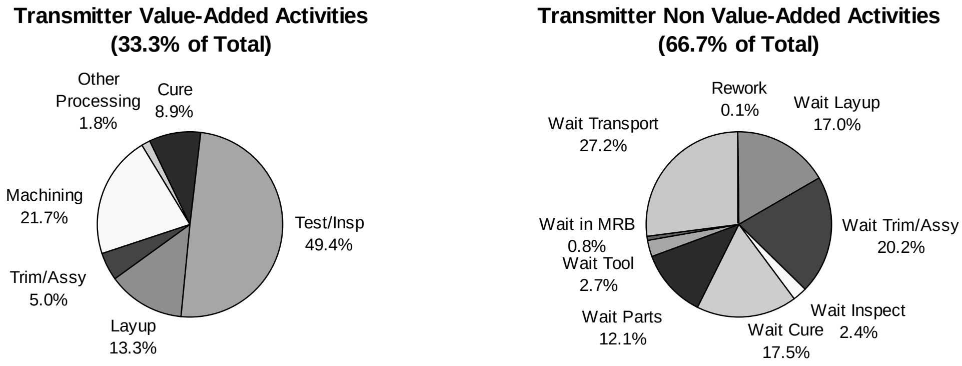

Figure 3: Value-Added and Non Value-Added Transmitter Activities

Cost driver elements that were collected in the model, such as the number of inspections, number of PARs, and the number of part moves, provide excellent performance measures of the system for evaluating proposed changes. Some of the cost drivers were quite surprising, particularly the number of part moves. The output statistics collected are for the total number of part moves during a one-year production run. Over 8,500 moves were required by Production Control for the antenna program alone.

4.3 Summary

At the time of this writing, there have not been any improvement projects analyzed with the model. The antenna program is just beginning low rate production and all efforts to this point have been focused on ensuring that adequate resources are available to begin the production phase. It is anticipated, however, that over the next year the emphasis will shift to improving performance and reducing costs on the program. As production data becomes available, the data collected from the pre-production prototype efforts can be updated, and the model can provide Industrial Engineering and the Production management with a tool for selecting improvement candidates and evaluating their impact.

It can be seen that using an ABCM approach to analyzing the antenna manufacturing process resulted in an expanded view of where the true production costs and cycle time components lie. The model should provide a useful baseline for evaluating alternative work sequencing schemes, batch sizes, production schedules, and assembly methods.

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