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Function Analysis and Decomposition Using Function Analysis Systems Technique

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ABSTRACT

The "Father of Value Analysis", Lawrence D. Miles, was a design engineer for General Electric in Schenectady, New York. Miles developed the concept of function analysis to address difficulties in satisfying the requirements to fill shortages of high demand manufactured parts and electrical components during World War II. His concept of function analysis was further developed in the 1960s by Charles W. Bytheway, a design engineer at Sperry Univac in Salt Lake City, Utah.

Charles Bytheway extended Mile's function analysis concepts and introduced the methodology called Function Analysis Systems Technique (FAST) to the Society of American Value Engineers (SAVE) at their International Convention in 1965 (Bytheway 1965). FAST uses intuitive logic to decompose a high level, or objective function into secondary and lower level functions that are displayed in a logic diagram called a FAST model. Other techniques can then be applied to allocate functions to components, individuals, processes, or other entities that accomplish the functions. FAST is best applied in a team setting and proves to be an effective methodology for functional decomposition, allocation, and alternative development.

BACKGROUND

Lawrence Delos Miles, or Larry Miles (1904 - 1985) is known as "The Father of Value Analysis." Larry was a design engineer for General Electric in Schenectady, New York under W. C. White, Manager of the Vacuum Tube Engineering Department from 1932 to 1938. During his six-year stay in this department Larry earned 12 patents for his new designs for vacuum tubes and related designs. Larry was very aware of unnecessary costs associated with the products that GE produced and knew there were better ways of producing these products (O'Brien, 1987).

One day in 1938, Miles burst into Mr. White's office and said, "Doesn't anyone in General Electric care what things cost?" This famous statement launched Larry's path toward the development of Value Analysis. Upon hearing this, Mr. White called Harry Erlicher, Vice President of Purchasing, and repeated his words. Mr. Erlicher said, "Send him over." (O'Brien, 1987)

During World War II, the United States found itself unprepared. Every manufacturing facility was fully scheduled with priorities running increasingly higher. Many priorities were AAA, or higher. Steel of all types was totally scheduled as were copper, bronze, tin, nickel, ball bearings, roller bearings, electrical resistors and capacitors, and all the vital products and materials required for the war effort (O'Brien, 1987).

Larry Miles was assigned the task of finding, negotiating and obtaining several of these vital materials, such as materials to expand production of tubo-superchargers from 50/week, to 1000/week for various warplanes including B-24s. Capacitors and resistors were required for skyrocketing military electronic needs as well as armament parts for expanding production of B-29s. In this environment, it was impossible to stop short of achieving the essential results (O'Brien, 1987).

Frequently, suppliers, already over-extended declined to increase schedules on new necessary products. This desperate situation forced Miles back to basics. He reasoned that if he could not get the product, then, he had to supply the <u>function</u> the product was to perform. He would work with suppliers to find ways using machines, labor, or materials they could get to provide the necessary function. Usually, a way was found to accomplish these functions which passed engineering tests and approvals making it possible to meet the ultra-tight schedules (O'Brien, 1987).

One day late in the war, a production manager gave Miles a schedule calling for thousands of a few dozen types of resistors and capacitors to be delivered to Oak Ridge, Tennessee weekly starting in <u>one</u> week.

Manufacturing schedules at the time were 9 months out, with 6 months firm. Miles was told this was an absolute requirement. Much later, it was learned these components were for the Manhattan Project (O'Brien, 1987).

Larry was able to secure these vital components since their priority was higher than any other. However, he had to find ways of replacing the components that were overridden. He worked with the vendors, making schedule changes and promising he would find some way to provide the essential functions of resistance and capacitance through a different shape or type of material or equipment, which would keep the vital electronic equipment on schedule (O'Brien, 1987).

In March of 1944, Miles accepted the responsibility of Manager of Purchasing at Locke Insulator, Baltimore, Maryland, a subsidiary of GE. He acquired line responsibility for delivery and cost of millions of dollars worth of materials and products each year. During the subsequent four years, he developed patterns of engineering, laboratory and purchasing teamwork, which limited costs and improved products. His thinking became more and more "What Function am I buying?" rather than "What material am I buying?" (O'Brien, 1987).

Thus, the concept of function analysis was born, which is the fundamental principal that Value Analysis or Value Engineering is based on. Later, in the 1960s, Charles W. Bytheway, an engineer at Sperry Univac in Salt Lake City, Utah (now Unisys), developed the methodology called Function Analysis Systems Technique, or FAST, to decompose a basic function and organize it into a logic diagram called a FAST model. This model provides new insights and opens opportunities to apply creativity to develop new ways, or alternative ways of accomplishing these functions.

FAST's ROLE WITHIN VALUE ENGINEERING

From this, one can draw several parallels between Value Analysis, or Value Engineering (VA/VE) and Systems Engineering (SE). First of all, both are requirements oriented and function based disciplines. Both focus on the functions required by a design, process, or service to accomplish its objective, or mission. In addition, both strive to develop alternatives designed to achieve only the required functions at the lowest cost while meeting the fundamental requirements of the customer. It is because of these parallels that Value Analysis/Value Engineering; especially the FAST technique, can play an important role within the context of Systems Engineering.

One of the important contributions FAST has for the SE discipline is it is synergistic way of developing, decomposing, and understanding the functions of any product, process, service, or organization. FAST, within the VA/VE context, utilizes a task force type system to get maximum performance from the individual and capitalize on performance by supplementing it with a group. This synergistic concept is important in that it presupposes that a group can achieve greater results than by the individuals separately. This is done by managing the complexities of interaction of the design engineering group by creating a task force composed of members of all the functional groups required to design and produce a product for a customer. It includes a member or members from design and project engineering, manufacturing engineering, purchasing, marketing, quality, operations, environmental, safety and health and others as required, thereby, increasing the decision making capacity beyond that of just the individuals involved. (Wixson, 1987)

In addition, in that it is a task force type activity, the labor required for the task is minimal since the group assembles only temporarily to get the job done. Then they go back to whatever it was they were doing before they met. This is the Integrated Product Team (IPT) approach also found in Systems Engineering. The difference being, however, that in VA/VE the team meets only temporarily, and in SE it is assembled for a much longer duration. In SE the IPT may be assembled for the duration of a particular design cycle.

This would be an opportunity to use Value Engineering to help the team understand the functional requirements, develop alternatives, and use it as a methodology to perform and document trade-off studies. Numerous VE studies may be performed to accomplish the goals of the IPT.

Teamwork helps to break down the barriers to communication created by organizational structures. It helps to develop a global view of the problem beyond the scope of a particular specialty and creates an understanding of all aspects of the problem so creative techniques can be applied effectively. (Wixson, 1987)

The fourth and perhaps most important element, creativity, requires the ability to visualize, to see beyond the existing state or condition. Creativity takes practice to break the self-applied barriers built up over years of educational and occupational indoctrination. This addresses the problem of bounded rationality. When properly applied, the synergistic group concept will reduce the propensity toward bounded rationality. (Wixson, 1987)

VA/VE employs some of the most powerful problem solving techniques ever devised. It combines the techniques of both divergent and convergent thinking to arrive at the best and most possible solutions to the problem. It employs the divergent techniques as brainstorming, FAST, matrix, and morphological; and convergent techniques such as rank and weight, gut feel index, and numerical function evaluation. (Wixson, 1987)

These are also common techniques used in Systems Engineering to evaluate trade studies. It is important to note the common objectives of both Systems Engineering and Value Engineering are to identify alternative ways of accomplishing the functions required by the system to meet the customer's requirements and choose the lowest cost alternative that meets these requirements. Therefore, function analysis is key to both disciplines.

THE FAST METHODOLOGY

In the Value Engineering methodology, function analysis is performed by an interdisciplinary team in a workshop setting. A Value Engineering workshop follows a structured six step job plan. Function Analysis is central to this methodology. In fact, if Function Analysis is not performed, the workshop can not be called a Value Engineering workshop. The Society of American Value Engineers is very clear on this issue. Figure 1 illustrates this six step job plan as outlined by SAVE in their "Value Methodology Standard."

In the classical method of Function Analysis developed by Larry Miles, only two words were allowed to describe each function, an active verb and measurable noun. For example, the function of a light bulb would be to "illuminate area", and not, "light room." The importance of using and active verb and measurable noun can not be emphasized enough. Later in the function analysis phase, values are assigned to these functions. These values can be dollars, weight, or any other pertinent value. These values are then used to evaluate the functions in terms of their importance, or value to the overall system.

The FAST modeling process starts with the facilitator asking several probing questions designed to identify the scope of the model, its objective function, and basic function, or basic functions. Three main questions that are asked are:

1. What is the problem, or opportunity we are here to discuss?
2. Why is this a problem, or opportunity?
3. Why is a solution necessary?

These questions are designed to identify the mission of the system while bounding the scope of the problem, or opportunity. By stating the mission of the system as a problem, or opportunity helps the team specify what the system is to accomplish.

PRE STUDY
User/Customer Attitudes Complete Data File Evaluation Factors Study Scope Data Models
VALUE STUDY
Information Phase Complete Data Package Finalize Scope ***Function Analysis Phase*** Identify Functions Classify Functions Function Models Establish Function Worth Cost Functions Establish Value Index Select Functions for Study ***Creative Phase*** Create Quantity of Ideas by Functions ***Evaluation Phase*** Rank and Rate Alternative Ideas Select Ideas for Development ***Development Phase*** Benefit Analysis Technical Data Package Implementation Plan Final Proposals ***Presentation Phase*** Oral Presentation Written Report Obtain Commitments for Implementation
POST-STUDY
Complete Changes Implement Changes Monitor Status

Figure 1: The VM Job Plan

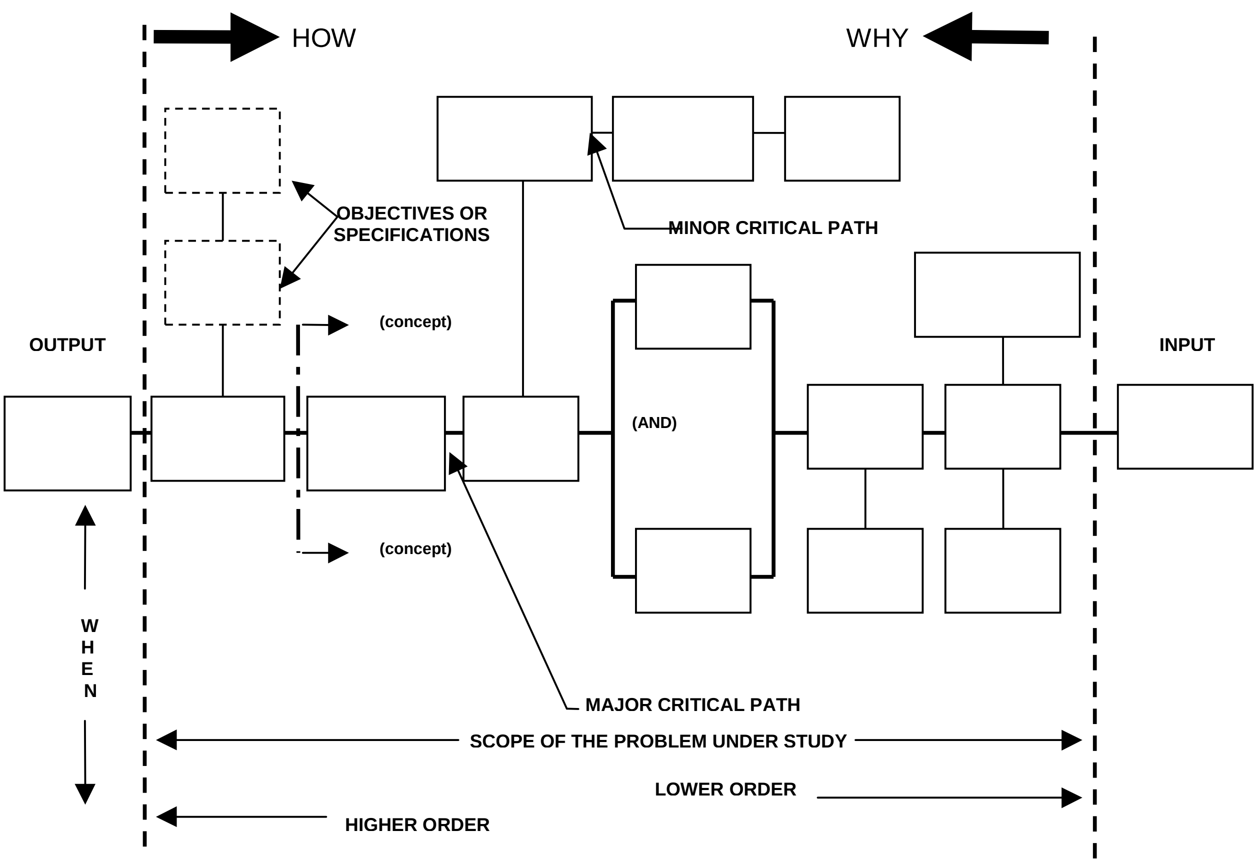
The basic structure of a FAST model looks somewhat similar to a process flow chart. However, there are some very significant differences (see figure 2). First, the blocks represent functions, and not process steps. The FAST model is a logic diagram, and not time oriented. There are several methods used to identify and decompose functions to start the model. One common method is to randomly "brainstorm" functions by starting with the objective, or mission of the system and brainstorming how it might be accomplished. Once a function is identified, the process is repeated until all possible ways are exhausted. Then, some of the identified functions become topics for the brainstorming and the process is repeated. One way to organize this is to put the answers to "How the objective is accomplished in the middle column of the three column matrix. Then the column on the left side is labeled "WHY" and the column to the right is labeled "HOW." Then, for every function that is put in the middle column, the answers to "HOW" and "WHY" this function is accomplished is placed in their respective columns.

After this brainstorming process is carried as far as it can go, all the functions are written on small 3M Postit Pads. Scope lines are drawn on a large piece of butcher paper, or flip chart papers, and the team participates in building the model. Of course, this could be accomplished using a computer and projection system. But, using the "poor man's CAD" system of Postit Pads on a large piece of paper gets the team more involved with the process. This is where organizational barriers start to breakdown, and better understanding of the functions begins.

Once the objective or higher order function is identified, it is positioned on the far left of the chart (figure 2). Then, the question, "How is this function performed?" is asked. The answer is then positioned directly to the right of the higher order function. This function is the basic function of the process, product, or service. It defines how the objective function is to be accomplished. For example, an objective function might be "convey information." There are numerous ways to "convey information." Once a function is chosen that answers the question, "How does the system 'convey information' is answered, that is the basic function. One example of a basic function for "convey information" could be "project image" as in the case of an overhead projector. Choosing "project image" fixes the basic function and specifies how the objective function is to be accomplished. If the answer is "deposit pigment" a totally different method has been defined. Therefore, once the basic function has been defined, it cannot be changed.

Notice that asking the question, "Why does the system "project image" is logically answered by, "convey information." This is called "intuitive logic." The FAST concept, based on this concept has the ability to test the selected functions to determine if they have been properly described, identified, categorized (i.e. basic, secondary, dependent, independent, supporting, etc.), as well as highlight key functions which may have been missed in the "random" method of identification. (Kaufman, 1977)

THE BASIC FAST MODEL



All functions to the right of the basic function describe the approach chosen to achieve the basic function. These are called "dependent functions." Any function on the HOW or WHY logic path is a critical path function. If the functions along the WHY direction enter the basic function, this forms a MAJOR critical path. MINOR critical paths can be formed if they depict how an independent, or supporting function is accomplished.

Independent functions are positioned above the critical path. Activities are positioned below the critical path. This vertical depiction of the functions is the WHEN direction. These functions happen at the same time, or, are caused by the critical path functions. Independent, or supporting functions are functions that do not depend on another function, or method selected to perform that function.

It should be noted here that there are several variations to the FAST model. The one described here is called the "Technical FAST" model. It is most useful in product development. One variation of the FAST model, primarily used for construction projects, keeps the critical path very simple, and at a high level of abstraction by removing functions that occur "all the time" from the critical path and positioning them in the top right-hand corner of the model. This is a less rigorous approach, however, it is valid as long as it meets the HOW/WHY logic of the model. The functional hierarchy method of function analysis, commonly used in SE, is also used in VA/VE. This satisfies the VM standards since it is a valid functional analysis approach.

FAST MODEL EXAMPLE

Now that you have an idea of the FAST concept, let's try an example. Remember the overhead projector mentioned earlier? We have already identified several functions. The objective, or higher order function is "convey information." The basic function, since we have chosen the overhead projector as the method that is going to be used to "convey information" is "project image. " Next we ask, "How do you 'project image'?" A logical answer to that question is by "generate light." These functions are place on the FAST model from left to right (see figure 3). Next the functions are tested in the "Why" direction. This will identify any missing functions because it won't sound right if there is one missing. Therefore, why do you "generate light?" Answer: To "project image." And, why do you "project image?' To "convey information." This process is continued until all the functions identified in the function brainstorming exercise are exhausted. The idea is to complete the critical path first. Once the critical path has been extended to the point it is out of the scope of the system, the remaining functions are positioned in the when direction to describe the supporting functions, independent functions, specifications and activities that fully describe the system. Note that it was decided that "transmit current" is out of the scope of the system. This is fairly obvious in this example since we know the overhead projector will be connected to a wall outlet to which the electric utility will "transmit current." Note also, that this is the major input to the system.

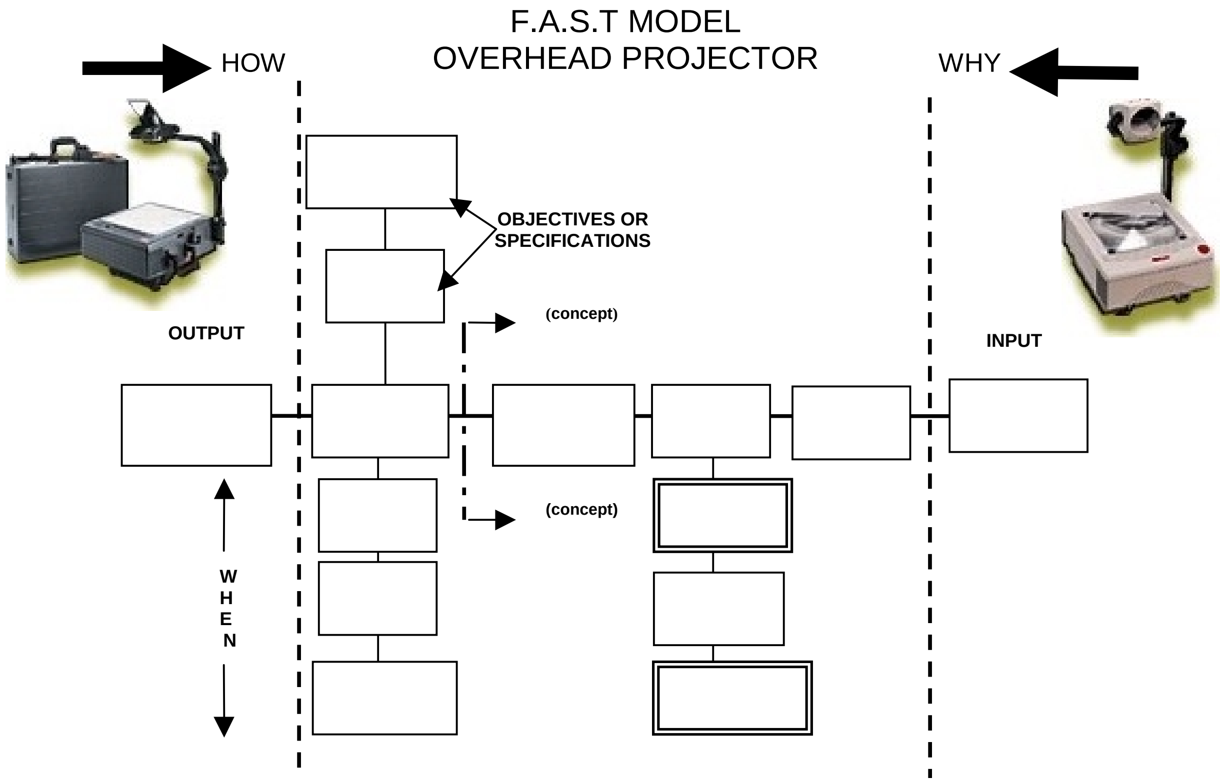
Now, let's take a look at some of the activities, or supporting functions. Notice the activities, or supporting functions in the "When" direction under "project image." These are read: "When we 'project image' we 'focus image', 'support image', and 'amplify image'." These are called supporting functions because they support a function on the critical path. These are functions that happen at the same time, or, are caused by the critical path function "project image." Generally, these functions also support a market concept, or customer requirements.

Now, note the supporting functions under "convert energy." The functions with the double lines around them, "generate heat" and "generate noise," are "unwanted", or "undesirable" functions. In the case of the overhead projector, the "generate heat" function is caused by the light bulb used to "convert energy" in order to "generate light." Excessive heat buildup significantly reduces the life of the light bulb. Therefore, the "dissipate heat" function has been added to resolve this problem. In doing so, however, it has caused another unwanted function, "generate noise."

Next, the objectives, or specifications can be added to the diagram. Note the "facilitate portability" and "allow safety" specification functions positioned over the basic function "project image." These are specified by the customer, regulations, or other sources. This is one way of depicting these functions, or, other methods simply position them in the upper right corner of the diagram. These are also called "all the time" functions.

Once the whole system has been described using the FAST model, opportunities can be identified for improvement in the system if this is a re-engineering project. Alternatively, if it is a product development effort, opportunities can be seen to avoid problems, improve the original design, and reduce cost. In the Value Engineering methodology, cost would be allocated to the functions in order to identify the high cost functions. Also, any unnecessary, or unwanted functions would be explored to see if they can be eliminated. Many times functions can be combined to reduce cost. This also has a desirable effect on reliability in many cases since the fewer parts a system has ,in general, the higher its reliability.

In this particular example, 3M has addressed the unwanted functions of "generate heat" and "generate noise." In some of their later models of overhead projectors they have replaced the fan with a heatsink to "dissipate heat." This reduces the cost of the system, makes it lighter, eliminates the noise previously caused by the fan, and facilitates portability.



CONCLUSION AND RECOMMENDATIONS

Function Analysis Systems Technique, or FAST, is a valuable technique that can be added to the System Engineering tool box. In addition to being an effective methodology for functional decomposition, it can be used to enhance the Integrated Product Team's understanding of the system through its synergistic effect when the FAST model is built by the IPT. Additional improvements will be seen if Value Engineering is applied as a way to identify design improvements, develop and evaluate trade-off studies, and build team and management consensus on the design concept. Also, FAST and VE can be used throughout the design process to identify cost trade-offs and opportunities for improvement.

BIOGRAPHY

James R. Wixson, CVS, CMfgE: Jim’s 22 years of experience includes work in Systems Engineering, Value Engineering, Industrial and Manufacturing Engineering, Project Management, Contracts and Pricing. He has a Bachelor of Science Degree in Industrial Engineering from the University of Utah and an MBA from the University of Phoenix. He is also a Certified Value Specialist through the Society of American Value Engineers and a Certified Manufacturing Engineer through the Society of Manufacturing Engineers.

Jim has worked for numerous companies including Unisys, Inc., Baker International, Inc., Raytheon Aircraft, and EG&G Idaho, Inc. Jim enjoys working with teams to solve large complex problems and develop designs for new products and projects. He is currently an Advisory Systems Engineer for Lockheed-Martin Idaho, Inc. in Idaho Falls, Idaho and lead systems engineer for stage II of the OU 7-10 Staged Interim Action Project, better known as the Pit-9 Project, at the Idaho National Engineering and Environmental Laboratory.

REFERENCES

Kaufman, J. Jerry, CVS, "FAST- A Thinking Discipline", 1977 SAVE Proceedings, p221.

Kaufman, J. Jerry, CVS., *Value Engineering for the Practitioner* (Third edition), North Carolina State University, 1990.

O'Brien, James, J., *Lawrence D. Miles Recollections*, Elinor Miles and Miles Foundation, 1987, pp 7-10.

Wixson, James R., "Improving Product Development with Value Analysis/Value Engineering: A Total Management Tool", 1987 SAVE Proceedings, p.51-66

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