Ingersoll-Rand Uses VE in New Product Development

A Strategy for Business Survival in the 21st Century

Don J. Gerhardt, Ph.D., PE, CVS

The organization’s ability to consistently develop high value products for its customers is paramount for survival. The use of value engineering tools in the “New Product Development” (NPD) process can help ensure that new products are developed that customers want and provide excellent return on the investment.

VA/VE evolved since its beginnings in the 1940s as an excellent productivity tool. VA/VE was originated by Lawrence Miles at the General Electric Co. The heart of VA/VE is analyzing the function of a product, process or service. Value is maximized by optimizing the equation:

\[ \text{Value} = \frac{\text{Function}}{\text{Cost}} \]

SAVE International has published a Value Methodology Standard which describes the VA/VE process. A process known as the value methodology job plan is used. Pre-study and post-study activity are part of the plan.

The plan consists of six sequential steps:

1. Information Phase
2. Function Analysis Phase
3. Creative Phase
4. Evaluation Phase
5. Development Phase
6. Presentation & Implementation Phase.

The term value analysis (VA) is used when the process is applied to existing products. The term value engineering (VE) is used when the process is applied to new products. Businesses in many countries are successful applying VA to existing products. The application of VE to NPD is more difficult. Japanese companies are the most successful in applying VE to NPD. Isuzu, as an example introduced, VA in 1959, and VE in NPD in 1979. Hitachi Construction Equipment introduced VA in 1960, and VE in NPD in the 1970s.

New Product Development

The percentage of successful new products that meet customer desires and organization’s operating income requirements has traditionally been low. Robert Cooper, in his three-part series on “Benchmarking Best NPD Practices,” indicates that approximately one in 10 product concepts succeed
The proper application of tools associated with VE can improve the success rate. The VE tools that are used in the VE process at Ingersoll-Rand include the following:

1. Product-Technology Roadmap
2. QFD/VOC Quality Function Deployment/Voice of the Customer
3. Competitive Benchmarking & Tear-down Analysis
4. Target Costing
5. Cost Tables and Part Cost Models
6. Value Engineering (Zero, First and Second Look)
7. DFMA Design for Manufacture and Assembly.

**Value Engineering in the NPD Process**

The term *value analysis* is used to apply the value principles to existing products and the term *Value engineering* is used to apply the principles to new products. When Larry Miles developed the value principles, they were first applied to existing products. Relatively few companies have progressed from VA on existing products to VE on new products. There are several reasons for this.

1. VA is relatively easy to apply and the results can be very significant. Organizations become satisfied with the results and do not move to the next level.
2. Most NPD processes are relatively complex and there is a reluctance to add more steps to the process
3. Many managers, engineers, financial professionals, marketing professionals and sourcing professionals are not aware of the tremendous impact VE can have on maximizing customer value and operating income
4. There are not many publications available that describe the process for successful application of VE in NPD

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<td>Function Analysis</td>
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<td>3 Product Design</td>
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<td>PFMEA</td>
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<td>6 Product Launch &amp; Production</td>
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Table 1. New Process Development (NPD) with value engineering.
Abbie Griffin published an article on new product development practices including a summary chart of prior best practice studies\textsuperscript{22}. VE in NPD is only recently showing up in NPD in the United States\textsuperscript{32}. It has been part of the Japanese NPD process for over 20 years. New product development processes typically have six stages. Booz, Allen and Hamilton were one of the first to document the six stages in 1969\textsuperscript{9}. Cooper added “Review Gates” to the stages to develop the “Stage-Gate” model of new product development\textsuperscript{12}. Figure 1 shows the six NPD stages and where VE tools should be applied. (See Table 1, above.)

Some Western companies have started to incorporate VE in the NPD process. An example is Pratt & Whitney Canada\textsuperscript{29}. Pratt & Whitney includes VE, function performance specification (FPS), QFD, parametric paired comparison, direct value measurement and risk assessment in their NPD process. Minimizing risk and eliminating quality problems provide high value to customers. Ingersoll-Rand Company incorporates design failure mode effects analysis (DFMEA) and process failure mode effects analysis (PFMEA) into its VA/VE process\textsuperscript{2}.

**Product-Technology Roadmap**

*Product-Technology Roadmapping* is a business planning tool that helps in developing the strategy to provide high value products that customers want. The process is illustrated in Figure 1. A forward cost model described by Albright\textsuperscript{4} can be used for future target costs for the product. The first step of the roadmap process is to identify customer drivers, define the market and develop a competitive strategy from the competitive landscape. This information is then used in the second step to map to the product

**Product-Technology Roadmap**

*A Business Planning Tool*

![Product-Technology Roadmap Diagram](Printed with permission from the Albright Strategy Group.)
drivers and a product roadmap is developed. The technology roadmap is developed in the third step with forward cost models. The technology roadmap is then mapped to the summary and action plan.

The forward cost model helps to set target costs over the time horizon of the roadmap plan. The cost targets are developed in the context of expected price ranges of future competitors’ products. An industry experience curve is one tool to help set cost targets. Planning is focused on technology elements that have the greatest impact on achieving the target costs.

**Voice of the Customer (VOC)**

It is essential to understand the qualitative and quantitative wants of the customer in order to provide value to the customer. There are a number of ways to obtain the VOC. These methods include:

1. Interviews (face to face and telephone)
2. Surveys (mail, phone, internet)
3. Observations
4. Customer feedback
5. Focus groups
6. Trade shows.

Typical market surveys do not have the necessary detail on the value perceived by the customer for various functions. Conjoint analysis, alternative solutions matrices and value mapping are techniques used to help understand what customers value. H. E. Cook of the University of Illinois at Urbana-Champaign has been developing more sophisticated methods to obtain VOC for VE in NPD. He co-authored a number of technical papers on VOC and VE that are published in SAE Publication SP-1266. SAE paper 970763 in the series describes a Direct Value (DV) survey method that combines elements of conjoint analysis, contingent valuation, prospect theory and choice theory. SAE paper 970764 discusses evaluating mail survey techniques for determining the value of vehicle options.

Cooper indicates in his recent work on benchmarking best NPD practices-III that “Voice of the Customer” and market input is one of the strongest discriminators between best and worst performers. You have to know what is of value to customers in order to provide high value products. Karlsson and Ryan describe an analytic hierarchy process (AHP) where customers compare requirements pairwise.

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**Figure 2: QFD House of Quality.**
according to their relative value and cost. The results can be used to make VE decisions that provide the highest value to customers.

Quality Function Deployment (QFD)

QFD is a tool that takes VOC data and presents it in a matrix format. QFD originated in Japan. It was first introduced at the Kobe shipyards of Mitsubishi Heavy Industries around 1972. Yoji Akao introduced QFD to the USA in 1983. The “Function Deployment” in QFD has its origin in the functional analysis of VE.

Larry Shillito was an expert on both QFD and VE. His book *Advanced QFD: Linking Technology to Market and Company Needs* explains the relations between QFD & VE. He uses the term *customer-oriented product concepting* (COPC) which combines several QFD matrices with VE. His later book discusses value measurement techniques to quantify structured VOC. James A. Rains, Jr. presented a recent paper on the relationship between QFD and VE. (See Figure 2.)

QFD analysis can contain up to 30 matrices. The first matrix is referred to as the *House of Quality* and is depicted in Figure 2. Room 1 contains the customer wants. The Planning matrix in Room 5 contains data from customers on the perceived value of our product and the competitor products. The Technical Matrix Room 6 contains competitive data from tests and tear-down analysis.

**Competitive Benchmarking and Tear-down analysis**

Competitive benchmarking not only involves benchmarking products, but also materials and manufacturing processes. The NPD-VE team needs to have knowledge of the best worldwide technology, materials and processes in order to provide products with the highest value to the customer.

The U.S. auto industry was one of the first implementers of product tear-down in the 1960s. Competitive vehicles, were reviewed for initial defects, tested, and operated for thousands of miles over various roads. Failures that occurred during testing and operation were reviewed. The vehicles were then torn down and the parts were displayed on tables in a large building. Engineers, manufacturing experts, and marketing personnel were invited to review and analyze the parts for ideas and best practice concepts.

General Motors introduced the static tear-down method to Isuzu in the early 1970s. Isuzu further refined the tear-down process and incorporated it into its VA/VE process. The process is documented in the book *Value Analysis Tear-Down* by Yoshihiko Sato and Jerry Kaufman. Sato and Kaufmann present the following data on the percentage of VA/VE ideas generated during their five steps (see Table 2).

<table>
<thead>
<tr>
<th>STEP</th>
<th>PERCENT CONTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Select competitor product</td>
<td>5%</td>
</tr>
<tr>
<td>2. Disassembly</td>
<td>30%</td>
</tr>
<tr>
<td>3. Analysis</td>
<td>40%</td>
</tr>
<tr>
<td>4. Display</td>
<td>10%</td>
</tr>
<tr>
<td>5. Examination</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 2. Five-step value analysis tear-down process.

Otto and Wood have a chapter in their product design book on product tear-down. They also discuss other VA/VE tools used in NPD including customer needs, product function and DFMA. They present a six step process for product benchmarking.

1. Form a list of design issues
2. Form a list of competitive or related products
3. Conduct an information search
4. Tear down multiple products in class
5. Benchmark by function
6. Establish best-in-class competitors by function
7. Plot industry trends

Ingersoll-Rand Company incorporated tear-down analysis into its VA/VE process in 1998. Current practice includes incorporating tear-down data in the Boothroyd Dewhurst DFMA software and links from part numbers to video clips of the disassembly. Tear-down analysis can also be provided by consulting firms. An example is Munro Associates.

Target Costing

Target costing originated in Japan at Toyota in 1959 following the introduction of value engineering in Japan. Target costing is the allowable cost of a product that yields the required rate of return. It is a simple concept, but multifaceted and difficult to implement for Western companies. Target costing involves understanding the value that customers are willing to pay for functions and the offerings of competitors in the market place. VA/VE is used to meet the target costs. Products are not put into production if the target costs are not met because required profit margins will not be obtained.

Traditionally many Western companies have established product price by adding profit margin to their cost of the product in the “Cost Plus” model (see Figure 3 below). Traditional “Cost Plus” models no longer work in the competitive global economy. The selling price is now driven by the market place. Companies must now use the “Target Costing” model if they want adequate profit margins (see Figure 4 below).


Target costs are established for parts manufactured in house and by suppliers. Value engineering is used to meet the target costs. Jeffrey Liker discusses an example at Toyota in his book The Toyota Way. Toyota established a joint venture, Trim Masters, Inc. (TMI) in 1994, to supply seats to Toyota’s Georgetown, Kentucky plant. The joint venture partners include Toyota Tsusho, Johnson Controls and Araco, Toyota’s long-term interior parts supplier in Japan. A target cost of 30% improvement was established for the 2004 model. Toyota worked jointly with TMI to meet the target cost by applying value engineering in the product design stage. An eight hour seminar on target costing is available from the Advanced Value Group.
Cost Tables and Part Cost Models

Japanese companies have been developing and using cost tables for many decades. Cost tables are detailed databases of cost information. The cost tables were originally developed for material costs, but now include all the manufacturing processes and design variables that affect cost. Originally the data was kept manually in tables. Computer costs models are now used. Most American companies do not have the detailed historical costs like the Japanese.

Yasuhiro Monden presents the following ways the Japanese use cost tables.

- Estimating costs for planned products or planned parts
- Predicting profitability at the manufacturing stage
- Setting price targets for parts to be purchased
- Checking market-competitiveness of purchased parts
- Presenting VE-related concepts to suppliers
- Negotiating reductions in purchased part prices at the manufacturing stage.

Japanese Companies typically have cost planning departments that maintain the cost tables. The cost planning department typically works in the product planning activity which reports to high level administration. The cost planning department has important functions which can include insuring that business plans are profitable, establishing target costs with engineering and managing the VA/VE activity.

Some American companies have developed cost models for certain commodities. Ford Motor Company has them for electrical wiring harnesses and heat exchangers. Part costing software is available from various suppliers. DFM part costing from Boothroyd Dewhurst is one of the most well known. The original data was developed with grants from the NSF in the early 1980s. Costimator software from MTI Systems is another. There are many small suppliers who have cost estimating software for individual manufacturing processes.

Value Engineering

Larry Miles developed the initial principles of value analysis at GE in the 1940s. The principle is based on maximizing value by analyzing functions of a product, process or service. Value is maximized by providing function and quality at the minimum cost. VE in NPD has evolved into three phases. The three phases are sometimes referred to as product development VE in Japan.

1. Zero Look VE
2. First Look VE
3. Second Look VE.

An example using an actuator illustrates the application of VE in the NPD process. The roadmapping and QFD/VOC activity have defined a product that requires the function of a rotary actuator with precise speed control. The actuator must be able to provide a required torque over a range of 0 to 500 RPM. The target cost is $100. The life requirement is 25,000 hours and 10 years without service or failure. The actuator will be used on a product that already has a diesel engine with a 100 amp 12 volt alternator and a
battery. Hydraulic flow from the power steering pump is available. The engine also has a gear drive that is available from a standard SAE PTO flange. A microprocessor controller already exists on the product but the interface control device is to be included in the $100 target cost.

**Zero Look VE**

The name Zero Look VE evolved as a consequence of the principles of VE being applied earlier and earlier in the NPD process. At one time First-look VE was the earliest that VE principles were applied in NPD. It became apparent that additional benefits could be obtained by moving VE further forward in the NPD process. Zero Look VE is the application of VE principles at the concept proposal stage. One of its objectives is to introduce new forms of functionality that did not previously exist. Sometimes this phase is referred to as *Product Planning VE*. Sawaguchi from the Japanese SANNO Institute describes the application of the “Combination of Patterns of Evolution of Technological Systems” from TRIZ with Zero Look VE and First Look VE. The Japanese refer to Zero Look VE and First Look VE as Product Development VE.

During the Zero Look VE creativity techniques such as brainstorming and TRIZ are used to establish possible solutions to meet the function and objectives. The team came up with the following three possible alternative designs and estimated costs that will meet the life and performance requirements after evaluating many alternatives.

- Electric motor using a PWM controller $150
- Hydraulic motor using valves to control the speed $200
- Mechanical gear drive using a CVT belt drive $250

The NPD VE team decides to proceed with a brushless electric motor concept using a pulse width modulated controller since it has the greatest opportunity of providing the highest value to the customer. The technology roadmapping indicated new lower cost MOSFET drivers that could be used for PWM control.

**First Look VE**

First Look VE focuses on the major elements of product design once the overall concept has been established during Zero-look VE. Target costs were established for the subsystems of the electric motor concept. The suppliers for the electric motor and controller were asked to participate in first look VE to meet the target costs. The NPD VE team was able to meet the target costs for the mounting hardware and wiring harness. Testing was conducted and the data indicated that the existing battery did not have to be upgraded to handle the motor load. The following table indicates that the total costs were reduced from

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>INITIAL ESTIMATE</th>
<th>TARGET COST</th>
<th>AFTER FIRST LOOK VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>$80</td>
<td>$50</td>
<td>$60</td>
</tr>
<tr>
<td>Controller</td>
<td>$50</td>
<td>$30</td>
<td>$40</td>
</tr>
<tr>
<td>Mounting Hardware</td>
<td>$15</td>
<td>$12</td>
<td>$12</td>
</tr>
<tr>
<td>Wiring Harness</td>
<td>$10</td>
<td>$8</td>
<td>$8</td>
</tr>
<tr>
<td>Battery Upgrade</td>
<td>$5</td>
<td>$4</td>
<td>$0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$150</strong></td>
<td><strong>$100</strong></td>
<td><strong>$120</strong></td>
</tr>
</tbody>
</table>

Table 3: Reduction of total costs of automotive components with First Look VE.
Second Look VE is applied to selected subsystems and parts where target costs are not being met. It can be applied during the last half of the planning stage and during the development stage. The objective is to improve the value, increase the functionality and lower the cost of the proposed components in order to meet the target cost and functionality objectives. Second-look VE activity in Japan closely resembles VA activity in the USA. Nakashima\textsuperscript{41} from Toshiba indicated that Second Look VE is not as profitable when compared to Zero Look VE and First Look VE in the product planning and development stage.

The NPD VE team applied Second Look VE to the motor and controller subsystems to meet the target costs. The initial concept was to use a brushless DC motor to meet the 25,000 hour life requirement. The team determined that they could use a lower cost brushed motor for the application if they could get the brushes to last for 25,000 hours. They worked with a brush supplier to use new material technology that provided the 25,000 brush life. The motor cost was reduced to $40. A simpler controller was used with the brushed motor and the cost was reduced to $25. The total cost was reduced to $81.

Design for Manufacturing and Assembly

The principles of DFMA are excellent to apply with VE in NPD. Pioneering research in DFMA was done by Geoffrey Boothroyd, Peter Dewhurst and Winston Knight. Geoffrey Boothroyd received grants from the National Science Foundation, SME and industry for research on DFMA. Material handling and part assembly times are summarized in charts in Boothroyd’s book\textsuperscript{8}. DFMA helps to reduce assembly time and combine functions to provide higher value products\textsuperscript{16}.

DFMA can be applied with the manual technique by looking up data in the charts. The data is also available with software. DFMA software is available from Boothroyd Dewhurst Inc.\textsuperscript{7} and from Munro & Associates\textsuperscript{40}. Selecting the optimum manufacturing process is important to provide the highest value products to customers. Swift and Booker from the University of Hull provide information on Process selection\textsuperscript{56}.

CONCLUSION

The application of VE in the NPD process can help insure that products are developed that provide high value to customers and excellent returns to the company. The VE tools are proven and work when properly applied. VE tools are becoming necessary for survival in the highly competitive global economy.

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Endnotes and Bibliography


Don J. Gerhardt, Ph.D., PE, CVS is a Senior Engineering Fellow at Ingersoll-Rand Company. He is also a member of SAVE International.
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