# VA/VE in Optimizing the Process of Semiconductor Industry in the Philippines

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## Abstract

In many industries, profitability and productivity are ongoing challenges. To increase productivity and profitability, process automation, innovation in technology, and process optimization are all required. Due to the intricacy of the work and the high manpower demands, enterprises in the autoparts manufacturing industry face supply chain challenges. A methodical strategy used to examine the function and its cost is Value Analysis and Value Engineering (VA/VE). It identifies a non-value-adding element that impedes the production of high-quality and dependable goods or processes. In this study, the wire harness manufacturing company used the VA/VE strategy to process optimization. Based on process VA/VE and a strategy for predicting human error, the production processes were examined (THERP). It draws attention to the crucial tasks involved in making wire harnesses. 15% of the faults in the assessment's wire assembly area involved inverted wires and incorrect assembly. A suggestion to enhance the assembly line process was developed using the analysis's findings

## Keywords
Value analysis, Value Engineering, Production Systems, Process Optimization, Wire Harness Assembly

## 1. Introduction
In many organizations, according to Chhabra and Tripathi (2014), VA/VE is used to increase productivity and cut costs. This method is being used by several business and economic sectors, such as the construction, service, and manufacturing industries, to increase profitability. The VA/VE technique is a rational way to examine how processes, machinery, facilities, services, and supplies perform in order to carry out their fundamental tasks at the lowest possible life-cycle cost. It is an effective tool for fixing system flaws and planning performance enhancements for any procedure or good. By concentrating on the functions that contribute the most to problems and their most likely causes, it is applied to produce noticeable improvements in quality and reliability (Sison et.al. 2018)

The Philippines has a thriving wire harness manufacturing business. In actuality, wire harness exports from the Philippines were ranked third worldwide (Sturgeon 2016). The auto parts sector, in which wire harness goods are essential elements, is expanding at a rapid rate alongside the automotive sector. However, despite this rapidly expanding need, the Philippines only has a small number of enterprises that produce wire harness goods.

Additionally, a sizable portion of the worldwide market was still untapped. According to the Department of Trade and Industry in the Philippines, the high level of knowledge and expertise required for wire harness production makes it difficult for local investors to expand (DTI 2016).

### 1.1 Objectives

The purpose of this study is to introduce and utilize VA/VE as a technique for maximizing manufacturer value through process optimization. In order to identify the crucial areas for improvement in the wire harness production line, it attempts to assess fundamental functions and cost implications. This study aims to offer a means of lowering and eliminating non-value-adding costs while preserving the necessary product reliability and quality. The goal of a strategy for human error prediction is to examine the likelihood that an error will occur. In addition, use of ProModel simulation will validate the recommended processes and assess the improvement productivity

## 2. Related Literature

Value Engineering is a tool used in the manufacturing sector to improve operations, lower production costs, and improve product and process design. Among the related literature, Zhang's Value Engineering approach in oilfield production by Zhang et al. (2010) discussed VA/VE as a useful methodology that, by establishing the value analysis based on function and cost analysis, results in an increase of initial investment and a decrease in life cycle cost in the operation. Additionally, Xu Jun (2008) focused on the utilization of value engineering in link chain enterprises. His research's objective was to determine the whole benefits by taking into account the reciprocal relationship between a function's cost and its contribution to organizational improvement. By examining the function and cost components of the provided project from a larger viewpoint, value engineering was also employed to optimize technological innovation projects. Value engineering and the fuzzy analytical method were coupled in Chen et.al (2010) to thoroughly choose the best appraisal among the projects that were chosen. Utilizing the owner's investment management funds through function-cost in the investment control of the construction project was another application of the value engineering study.

The study by Palisoc et al. (2019) also aims to enhance the remote production setup of a media broadcasting company while considering trade-offs based on pertinent limitations including Material VA/VE, Product VA/VE, Process VA/VE, Ergonomics, Economic, and Productivity. Additionally, several studies in the literature (Duque et al. (2016); Navarro, M.M., and Navarro, B.B.) seek to maximize production employing a pertinent Design Trade-Off (2016).

## 3. Methods

In order to gain process optimization based on the production line's functions and costs, this study applied the VA/VE approach to analyze the line. Process VA/VE techniques were used, such as functional analysis and cost analysis. Techniques for reducing and probabilizing human error were also used to better evaluate the issues with mistake.

The following logical steps were applied in VA/VE for the production line for wire harnesses..

**Information Phase**

1. Data collection – Identify type of data for collection and present issues in the production line.

**Functional Analysis Phase**

2. Functional Analysis – Review of Functions and specifications.
3. Cost Identification – Determine the operating and labor cost.

**Creative Phase**

4. Desired Value Expectation – Explore other ways of getting the desired value. Examine critical functions for improvement.
5. Cost of improved process – Determine the cost of the improved process.

**Evaluation Phase**

6. Functions Evaluation –Simulation was used to evaluate increase in productivity from the process alternative solution.

**Development Phase / Implementation Phase**

7. Execution and implementation of selected ideas – this phases depends on the subject company's decision for implementation.

### 3.1 Information Phase

One of the top producers of power cables and wire harness items in the Philippines is the company under discussion. With their dedication to provide consumers good quality products at low prices and on time, they are a well-known industry pioneer. Their products are utilized in power generators, air conditioners, and motorcycles. The product line is currently being steadily expanded for both domestic and international consumers.

The wire cutting, accessory attachment, wire termination, wire assembly, and final testing procedures are separated into five basic categories for the wire harness production line. The researcher observed the production line workers and spoke with them face-to-face. Every team in various divisions is certain that meeting their quota and preventing production faults are their top priorities. To control production faults, the company used a quality control system.

The various categories of production line errors are illustrated in Table I below. Inverted wires (43% of the productions have this problem) and loose crimps (17% of them) are the two biggest mistakes. The improper wire placement in the housing results in a crossed or inverted wire. It is the initial step in the assembly line for wire harnesses. The wire harness assembly line experienced these kinds of mistakes. Where the wires are loosened in the housing is known as loose crimp. In the termination portion, it frequently occurred**.**

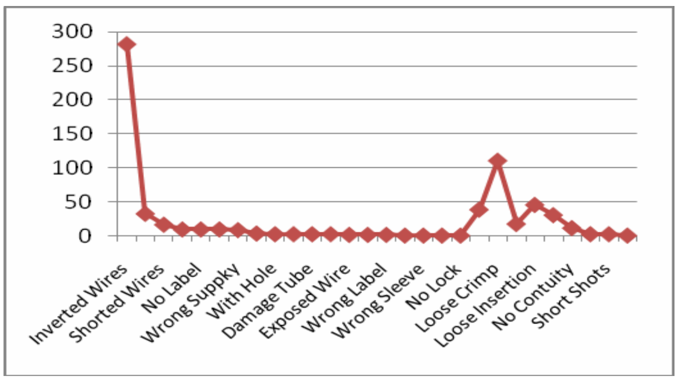



Figure 1. Classification of errors

Inverted wires are categorized as human errors by the company's quality control department. In the assembly, this subprocess is a manual process. Rework procedures are used to fix the 15% of inverted wire faults.

### 3.2 Function Analysis

The Function Analysis System Technique (FAST) is a methodical graphic that shows the logical connections between various project functions (Tan,2010). Figure 2 FAST graphic below illustrates the five functions that make up the fundamental wire harness production processes: (f1) Wire Cutting, (f2) Attaching of Wire Accessories, (f3) Terminating of Wires, (f4) Wire Assembling, and (f5) Final Testing.

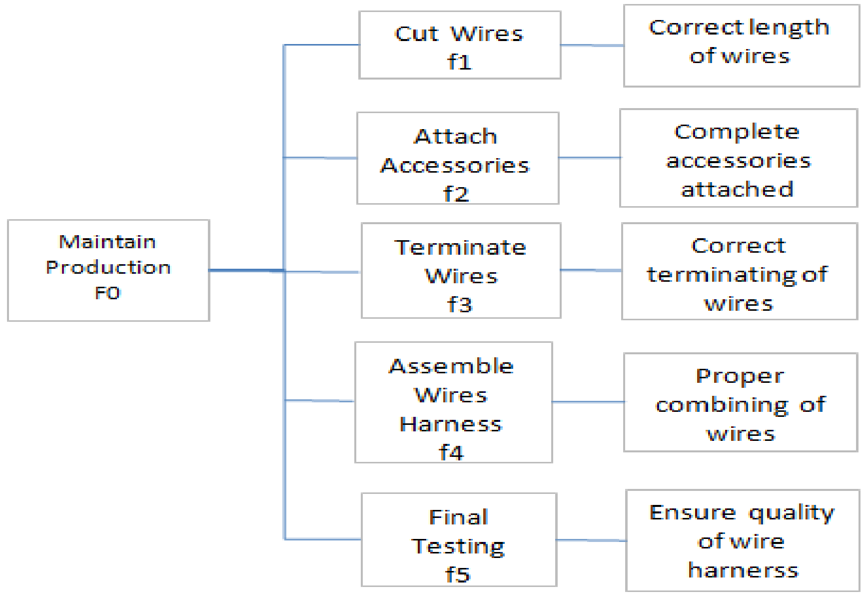



Figure 2. FAST diagram of Wire Harness Production

Technical specialists in the fabrication of wire harnesses are asked to rank the fundamental duties in the production line depicted in Table I according to their level of importance. where Function Importance Coefficient is calculated by dividing the average score for each function by the sum of all function scores.

Table 1. Weight of Basic Function

| Num | Basic Functions | Expert 1 | Expert 2 | Expert 3 | Expert 4 | Expert 5 | Total Score | Average Score | Function Importance Coefficient |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Wire / Tube Cutting (f1) | 25 | 25 | 20 | 25 | 20 | 115 | 23 | 0.23 |
| 2 | Preparation of Accessories (f2) | 10 | 15 | 15 | 15 | 15 | 70 | 14 | 0.14 |
| 3 | Terminating (f3) | 30 | 25 | 25 | 25 | 25 | 130 | 26 | 0.26 |
| 4 | Assembly (f4) | 25 | 25 | 30 | 25 | 30 | 135 | 27 | 0.27 |
| 5 | Final Testing (f5) | 10 | 10 | 10 | 10 | 10 | 50 | 10 | 0.10 |
|  | Total | 100 | 100 | 100 | 100 | 100 | 500 | 100 | 1.00 |

### 3.3 Cost Analysis

The value engineering cost analysis application by Zhang et al. (2010) were used to assess the total production cost (C) that include labor cost ($C_h$) and operation cost ($C_0$).

$$C = C_h + C_0 \tag{1}$$

The computation for cost modulus ($KC_i$) can be formulated below:

$$KC_i = \frac{(C_{hi} + C_{oi})}{(\sum C_{hi} + \sum C_{oi})} \tag{2}$$

Table 2. Calculation of the Production

| Function | Amount of labor (person) | Labor cost (Php) | Operation cost (Php) | Total cost (Php) | Weight of cost |
|---|---|---|---|---|---|
| f1 | 10 | 1,797,060 | 32,400,000 | 34,197,060 | 0.165 |
| f2 | 10 | 1,797,060 | 69,300,000 | 71,097,060 | 0.342 |
| f3 | 16 | 2,875,296 | 42,300,000 | 45175296 | 0.217 |
| f4 | 21 | 3,773,826 | 17,100,000 | 20,873,826 | 0.100 |
| f5 | 2 | 359,412 | 36,000,000 | 36,359,412 | 0.175 |
| **Total** | **59** | **10,602,654** | **197,100,000** | **207,702,654** | **1.000** |

The aforementioned labor and operation statistics were only gathered for three months for a single model type in the fabrication of wire harnesses.

## 3.4 Value Analysis of Production Operation

The principle of Value Engineering, the value of production operation can be expressed as:

$$V = \frac{F}{C} \tag{3}$$

In this study, the value coefficient was use to evaluate the functions that contributes more value in the production show in Table 3:

Table 3. Value Coefficient of wire harness production

| Function | Function importance coefficient | Function Cost coeffienct | Value coefficient |
|---|---|---|---|
| f1 | 0.23 | 0.165 | 1.397 |
| f2 | 0.14 | 0.342 | 0.409 |
| f3 | 0.26 | 0.217 | 1.195 |
| f4 | 0.27 | 0.170 | 1.590 |
| f5 | 0.10 | 0.184 | 0.543 |
| Total | 1.00 | 1.000 | |

## 3.5 Process VA/VE

The crucial part of the production line that requires the most improvement is the wire assembly. The majority of the rejects from the identification phase are located in this wire harness assembly area. Cost analysis's conclusion captures this section's high worth. This implies that any enhancements made to this component may also result in considerable cost savings. The normal and standard time are determined using time and motion analysis, as indicated in Table 4 below.

Table 4. TMS Summary Process in the Assembly Line

| Job Category | Functions Verb | Functions Noun | Rating Factor | Normal Time in minutes | Normal Time In Hours | Allowance Factor | Standard Time | Rounded Standard Time for Estimates (HR) | Rounded Standard Time for Estimates (Minutes) |
|---|---|---|---|---|---|---|---|---|---|
| Preparation | Sorting | Wires | 110% | 11.60 | 0.19 | 115% | 13 | 0.22 | 12 |
| Preparation | Inserting | Wires | 110% | 15.19 | 0.25 | 115% | 17 | 0.29 | 15 |
| Preparation | Remove | Rubberbands | 110% | 10.72 | 0.18 | 115% | 12 | 0.21 | 11 |
| Assembly | Sorting | Wires | 110% | 12.33 | 0.21 | 115% | 14 | 0.24 | 12 |
| Assembly | Inserting | Wires to Housing | 110% | 9.87 | 0.16 | 115% | 11 | 0.19 | 10 |
| Assembly | Inserting | Wires to PVC rubber tube | 110% | 5.77 | 0.10 | 115% | 7 | 0.11 | 6 |
| Assembly | Inserting | Wires to connector | 110% | 16.65 | 0.28 | 115% | 19 | 0.32 | 17 |
| Assembly | Sorting | Wires | 110% | 11.11 | 0.19 | 115% | 13 | 0.21 | 11 |
| Assembly | Inserting | Wires to spare fuse | 110% | 3.39 | 0.06 | 115% | 4 | 0.06 | 3 |
| Assembly | Combining | Wires | 110% | 26.23 | 0.44 | 115% | 30 | 0.50 | 26 |
| Assembly | Sorting | Wires | 110% | 10.37 | 0.17 | 115% | 12 | 0.20 | 10 |
| Assembly | Inserting | Wires to components | 110% | 31.29 | 0.52 | 115% | 36 | 0.60 | 31 |
| Assembly | Inserting | Wires to PVC rubber tube | 110% | 6.49 | 0.11 | 115% | 7 | 0.12 | 6 |
| Assembly | Combining | all wires to PVB Rubber tube | 110% | 4.12 | 0.07 | 115% | 5 | 0.08 | 4 |
| Finishing | Get | wires | 110% | 22.11 | 0.37 | 115% | 25 | 0.42 | 22 |
| Finishing | Inserting | Housing | 110% | 38.38 | 0.64 | 115% | 44 | 0.74 | 38 |
| Finishing | Align | Board | 110% | 5.16 | 0.09 | 115% | 6 | 0.10 | 5 |
| Finishing | wait | Wires | 110% | 3.57 | 0.06 | 115% | 4 | 0.07 | 4 |
| Finishing | Pushes | Board | 110% | 3.17 | 0.05 | 115% | 4 | 0.06 | 3 |
| TOTAL | | | 110% | 247.52 | 4.125 | 115% | 285 | 4.744047 | 248 |

## 3.6 Technique for Human Error Prediction

The Technique for Human Error Prediction (THERP) is a tool used to forecast the dependability of human performance. This technique forecasts the frequency of human error. It is a technique for forecasting human mistake rates and assessing the degradation of a human-machine system that is expected to be brought on by human errors, together with other factors like equipment reliability and operating practices. THERP makes decisions regarding specific scenarios using performance-shaping criteria. THERP can be applied to design analysis, workforce selection, system effectiveness prediction, and training requirement determination. The probability that a class of errors will lead to system failure is given by:

$$Q_i = 1 - (1 - F_i P_i)^{n_i} \tag{4}$$

Table 5. THERP Probability Error

| Item | Final Assembly Operation | Human Error Probability | Error Factor |
|---|---|---|---|
| 1 | Sorting Wires base on types | 0.1 | 5 |
| 2 | Inserting wires to housing | 0.4 | 5 |
| 3 | Inserting wires to tube | 0.02 | 5 |
| 4 | Inserting wires to connectors | 0.05 | 5 |
| 5 | Inserting wires to fuse | 0.02 | 5 |
| 6 | Combine wires in assembly board | 0.1 | 5 |

The chance of human error for each subtask on the wire harness assembly line is shown in Table 5 above. The likelihood of error is considerable when wires are inserted into housing.

### 3.7 Suggested Improvement in the Wire Assembly Section

With the above analysis, we can develop the following innovative solution in the wire harness assembly line.

a. Process improvement on insertion of wires to its housing.
b. Eye screening program for workers to check workers color of wires detection capability.
c. Maintenance on wire harness board to organize wire selection and attachment.
d. Use of hand taping design to avoid disconnection of wires.
e. Improve holder design of wire holder for easier selection of wires for housing procedure.

### 3.8 Validation through Simulation

The ProModel simulation is employed to verify the outcomes of the enhanced procedure. It is a modeling tool for manufacturing systems that combines simulation and animation. ProModel was applied in the manufacturing sector research by Marcelo et.al (2016) to standardize the manufacturing process. The simulation study was created to determine the extent to which the models' modifications affected throughput rate. Figure 3 and 4 shows the pro model simulation in wire harness assembly operation and the number of exits in the system.

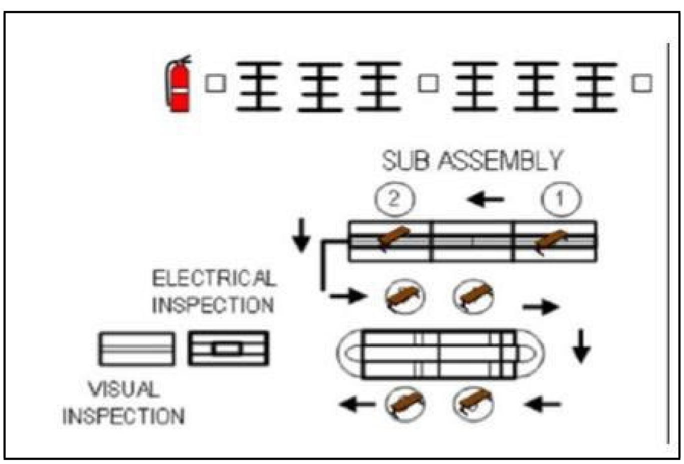
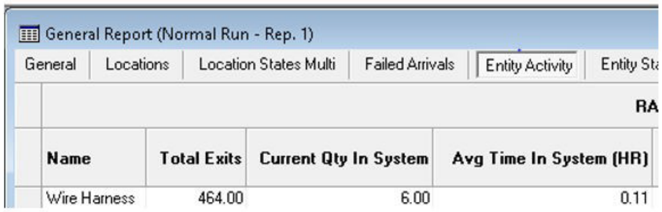



Figure 3. ProModel Location




| Name | Total Exits | Current Qty In System | Avg Time In System (HR) |
|---|---|---|---|
| Wire Harness | 464.00 | 6.00 | 0.11 |

Figure 4. Pro Model Result

## 4. Results and Discussion

The Process VA/VE demonstrates that most production line activities require additional reductions in operational costs in order to boost their value. Processes that don't add value, like mistakes in the wire harness assembly line, are stopped. The sub-process of placing the wire into its housing had the highest mistake probability, with a value of 0.4, according to the technique used to forecast human error. The suggested change concentrated on how to enhance this component of the process. The production's 13% productivity was verified by ProModel Simulation.

## 5. Conclusion

The wire harness production process was optimized in this work utilizing the VA/VE strategy. The answer demonstrates how conducting a functional analysis on a production's key process and taking the necessary immediate action can potentially result in considerable increases in output and profit.

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## Biographies

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