# *ORTHOGONAL ARRAY TESTING STRATEGY (OATS) TECHNIQUE* JEREMY H. HARREL A LITERATURE REVIEW

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**ABSTRACT**

Knowledge about experimental design is mostly done in agriculture or animal husbandry, it is still rarely done in other fields, especially in marketing. However, experimental design research was then carried out in the industrial field, and some has also been done for marketing. Orthogonal Array (OA) is one part of a group of experiments that only use part of the total conditions, this part can be only half, a quarter or an eighth of a full factorial experiment. It can be said that Orthogonal arrays are used to design efficient experiments and analyze experimental data by using only part of the total conditions so that in this case it minimizes the number of experiments, where the number of experiments will be able to provide as much information as possible about the influencing factors. This discussion will also discuss how to use Orthogonal Array in research on industrial products. The use of experimental design which continues to develop will later be very useful in marketing to see how a product is desired by consumers and can make the resulting product better and can save costs so that the use of this experimental design research can be used in decision making for the use of a product of goods and services.

**Keywords**: Experimental Design; Orthogonal Array; Consumer

## INTRODUCTION

In making industrial decisions on a product to be marketed, there will definitely be observations with research to determine the quality of a product. In statistical quality control, the problem-solving techniques used will be used to monitor, analyze, or control, analyze and most importantly improve the product, where the process uses statistical methods.
In principle, quality is determined and measured based on product quality characteristics which consist of several general properties, namely as follows:

1. Physical which can be in the form of weight, length, size, volume and others
2. In relation to the five senses which are also called sensory, namely regarding taste, appearance, model, color, shape and so on.
3. Related to time orientation, namely regarding maintainability, serviceability and reliability and others.
4. Cost-oriented, namely related to the cost dimension, namely the price or cost of a product that must be paid by consumers.

When we talk about measuring the quality performance of a product, there are three levels that will be carried out, namely:

1. Initial measurement, which is carried out to measure the process carried out by measuring the activities and steps of the process and controlling the desired characteristics, for example how long the response is when customers ask about a product via the website or by telephone, the time of delivery of goods to customers and others.
2. Measurements carried out at the output level, in this measurement is how to measure the comparison of the output that has been produced to the specifications that customers want. For example, whether the product produced has defects such as several car products that have been recalled or by seeing if there are specifications that are not in accordance.
3. The next measurement is measurement at the outcome level where at this stage it will assess whether a product has met the needs or expectations desired by consumers. By looking at complaints from customers and how many items are returned by customers.

## LITERATURE REVIEW

### General View of Experimental Design

Montgomery (2008) in his book defines experimental design as a systematic effort in designing a design by conditioning several factors. Experimental design must follow the experimental method. Quoted from Suryaningsih (2010), experimental design is all the processes required in planning and implementing an experiment. In a broader sense, experimental design includes the following processes:

1. Identifying problems in the experiment
2. The identified problems are then viewed in the conceptual framework
3. Formulating by making specifications of the objectives and hypotheses that will later be tested
4. Conducting or building research
5. Selecting and defining the variables to be measured
6. Determining the procedures and sampling techniques used
7. Compiling the tools and techniques used to collect data
8. Coding, editing and processing data
9. Analyzing data and choosing statistical procedures
10. Then reporting the results of the research.

In research we know that there are factors that can cause product diversity, namely interference factors. There are 3 types of disturbances, namely:

1. External factor disturbance
   As the name implies, the meaning of external disturbance factors is disturbances from sources of variability originating from outside the product. This external disturbance is closely related to the environment where this condition can affect the ideal function of a product.
2. Internal factor disturbance
   Internal disturbances can be related to factors that can damage a product so that it does not reach its target.
3. Inter-unit disturbance
   Disruptions that occur due to diversity from unit to unit are closely related to factors that can cause differences between each product that has been made even though they are in the same specifications. This variation cannot be avoided in product parameters from one unit to another.

As for the disturbance factor, it cannot be simply eliminated, because this disturbance factor could be in the system. If the disturbance factor cannot be eliminated, it will affect the quality characteristics of the product, resulting in the product not reaching the target value. By looking at this, in the process of a product, it tries to reduce losses in the production process by controlling the factors on the disturbance factor so that the product specifications will be clearly identified and the quality characteristics are not sensitive to disturbances.

*P-DIAGRAM*

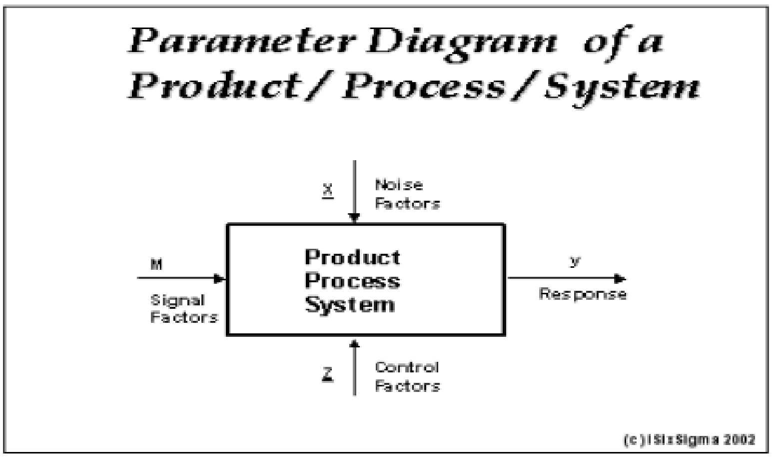



Figure 1. Parameter Diagram of Product Proses System

There are 4 approaches that can be taken to reduce the variance or diversity that occurs, namely:

1. By finding and eliminating the causes of differences
2. Taking a way to narrow tolerance
3. Using a robust design
4. And taking a drastic way, namely by throwing away defective products.

By looking at this approach, the best way to reduce product diversity is to carry out and apply a robust design. This method consists of making product performance that is not sensitive to disturbance factors. In its implementation, the tolerances carried out do not have to be too tight, and the work environment does not have to be controlled so tightly, it can use more affordable or cheaper materials so that it is cost-effective.

**Classification in Experimental Design**

Because there are many types of experimental designs, they are then classified based on the allocation or placement of factor combinations (treatments) and the degree of randomization of the experiment (Park, 1996). Where the classification is as follows:

1. Factorial Design
   This experimental design is to find all possible combinations of treatments formed from the factors that have been considered. The order is determined completely by being done randomly when the combination is selected. Fractional Factorial Design This experimental design is to investigate part of all possible combinations of treatments. Similar to factorial design, the order in which the treatment combinations are selected is completely random. Included in this class are Orthogonal Arrays designs, Plackett-Burman designs, Latin Square designs, and Graeco-Latin Square designs. This design is used when the cost of conducting an experiment is high and time-consuming.
2. Randomized Complete Block Design, Split-plot Design, and Nested Design.
   A design in which each block contains all possible treatments, and the only randomization of treatments is within that block, is called a randomized complete block design.
   All possible combinations of treatments can be done in these designs, but there are some restrictions on the use of randomization.
3. Incomplete Block Design
   In the Incomplete Block Design design, it is used when we cannot run all treatments in each block due to lack of experimental apparatus or inadequate facilities. If each treatment is not presented in each block in a randomized complete block design, it is called an incomplete block design.
4. Response Surface Design and Mixture Design
   The purpose of the response surface design is to explore a regression model to find a functional relationship between the response variable and its factors or independent variables, and is also used to find the optimal conditions of these factors.

***Orthogonal Arrays***

As mentioned above, Orthogonal Array (OA) is one part of the Fractional Factorial Design experimental group that only uses part of the total conditions, where this part may be only half, a quarter or an eighth of a full factorial experiment.

When this happened, this "numerical curiosity" was then taken up by the statistical community and used in statistical test design. Genichi Taguchi was the first proponent of orthogonal arrays in test design. His technique, later known as the Taguchi Method, has been a mainstay in every experimental design in manufacturing for decades.

The Taguchi method was introduced by its founder, (Taguchi, 2001) a quality control consultant. This is a new methodology in engineering which then aims to improve product and process quality and can reduce costs and resources to a minimum.

In the Taguchi method, a matrix called an orthogonal array is used to determine the minimum number of experiments that can provide as much information as possible on all factors that affect the parameters. The most important thing about orthogonal arrays is the selection of the combination of levels of input variables for each experiment.

According to Taguchi, there are two general aspects of quality, namely design quality and conformance quality. Design quality is the variation in quality levels in a product that is intentional, while conformance quality is how well the product meets the specifications and allowances required by the design.

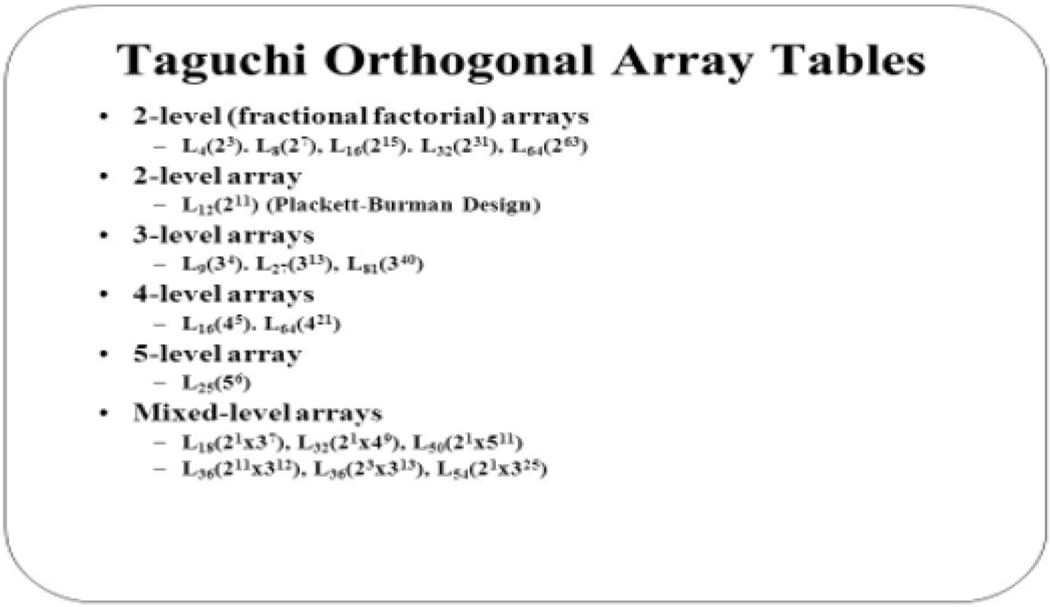
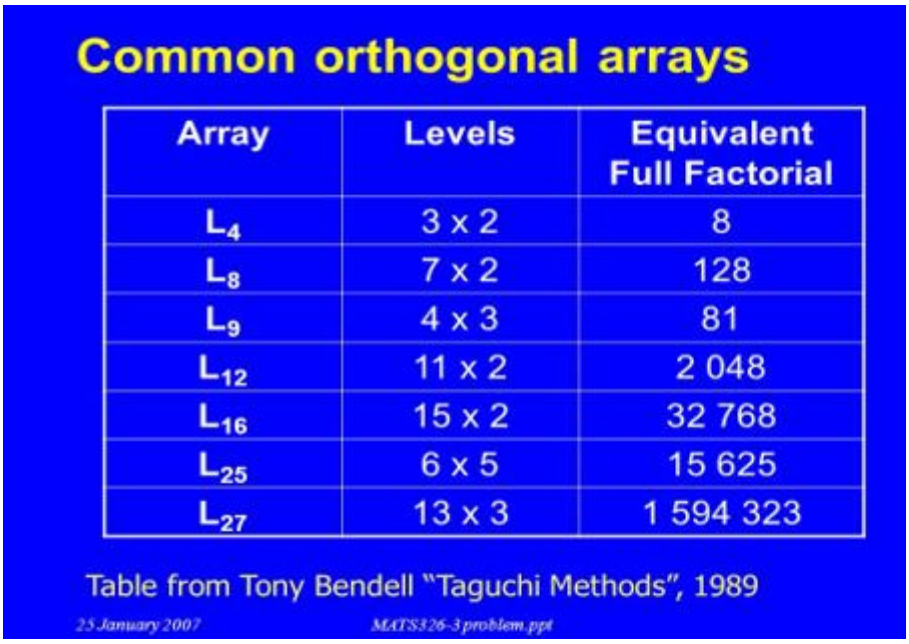



Figure 2. Taguchi Orthogonal Array Tables

In the Taguchi method, a special set of matrices called Orthogonal Arrays is used. This standard matrix is how to determine the minimum number of trials that can provide as much information as possible on all factors affecting the parameters. So, the most important part of the Orthogonal Array method lies in choosing a combination of levels of input variables for each trial.


Common orthogonal arrays

| Array | Levels | Equivalent Full Factorial |
|---|---|---|
| $L_4$ | 3 x 2 | 8 |
| $L_8$ | 7 x 2 | 128 |
| $L_9$ | 4 x 3 | 81 |
| $L_{12}$ | 11 x 2 | 2 048 |
| $L_{16}$ | 15 x 2 | 32 768 |
| $L_{25}$ | 6 x 5 | 15 625 |
| $L_{27}$ | 13 x 3 | 1 594 323 |

Table from Tony Bendell "Taguchi Methods", 1989
25 January 2007 MATS326-3problem.ppt

Figure 3. Common Orthogonal Arrays

According to Wahjudi et al. (2001), Orthogonal Array has the following benefits:

1. The conclusions drawn can cover the scope of the control factors and each of its levels as a whole
2. It saves a lot of time in carrying out experiments because it does not use the full factorial experiment principle like ordinary experiments but uses the fractional factorial experiment principle. This means that not all level combinations must be tested, but only a few. To determine which level should be used in data collection, it must refer to the standard OA model.
3. It has ease of data analysis

By looking at this approach, the best way to reduce product diversity is to do and implement robust design. This method consists of making product performance that is not sensitive to disturbance factors. In its implementation, the tolerances that are carried out do not have to be too tight, and the work environment does not have to be controlled so tightly, it can use more affordable or cheaper materials so that it is cost-effective.

**Determination and Selection of Orthogonal Array**

In determining the type of OA, two things must be considered, namely:
1. The number of levels and factors to be studied.
2. Interaction in factors.

## RESEARCH METHOD

Taguchi method uses a special set of matrices called Orthogonal Arrays, to determine which combination of factors and levels will be used in an efficient experiment and to analyze the experimental data. Orthogonal Array is a fractional factorial matrix that ensures a balanced comparison between the levels of factors or their interactions in the resulting combination. Orthogonal arrays are used to determine the minimum number of experiments that can provide as much information as possible on all factors that affect the parameters. The most important part of Orthogonal Array lies in the selection of the combination of levels of the input variables for each experiment (Ross, 1989).

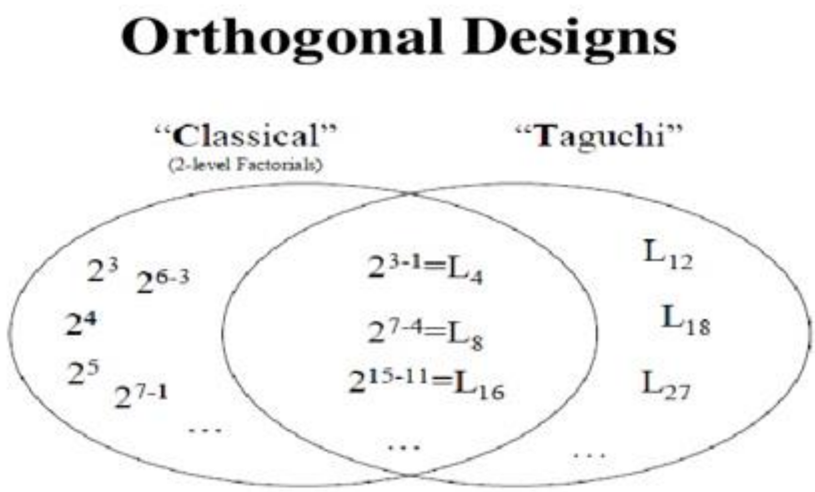



Figure 4. Orthogonal Designs

Orthogonal Array is a matrix of numbers arranged into a number of rows and columns. Each row represents the level of a factor in each experiment (run), and each column represents a particular factor or condition that can change from one experiment to another. The array is called orthogonal because each level of each factor is balanced and can be separated from the influence of other factors in the experiment. Orthogonal Array is a matrix of factors and levels that do not carry the influence of other factors or levels (Park, 1996).

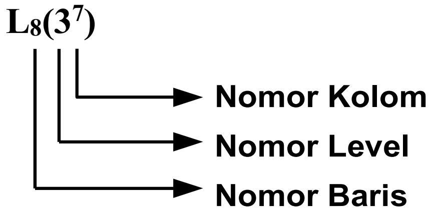



Image caption:

- L = information about the Orthogonal Array
- The number in the row indicates the number of trials needed when using the Orthogonal Array
- The column number is the number of factors observed in the Orthogonal Array
- The level number indicates the number of factor levels

**Select a Taguchi Orthogonal Arrays Based on DOF**

| Orthogonal Array | No. Runs | Max. Factors | Max. of columns at these levels | | | |
|---|---|---|---|---|---|---|
| | | | 2-level | 3-level | 4-level | 5-level |
| L4 | 4 | 3 | 3 | | | |
| L8 | 8 | 7 | 7 | | | |
| L9 | 9 | 4 | | 4 | | |
| L12 | 12 | 11 | 11 | | | |
| L16 | 16 | 15 | 15 | | | |
| L'16 | 16 | 5 | | | 5 | |
| L18 | 18 | 8 | 1 | 7 | | |
| L25 | 25 | 6 | | | | 6 |
| L27 | 27 | 13 | | 13 | | |
| L32 | 32 | 31 | 31 | | | |
| L'32 | 32 | 10 | 1 | | 9 | |
| L36 | 36 | 23 | 11 | 12 | | |
| L'36 | 36 | 16 | 3 | 13 | | |
| L50 | 50 | 12 | 1 | | | 11 |
| L54 | 54 | 26 | 1 | 25 | | |
| L64 | 64 | 63 | 63 | | | |
| L'64 | 64 | 21 | | | 21 | |
| L81 | 81 | 40 | | 40 | | |

Figure 5. Taguchi Orthogonal Arrays

For two levels, the OA table consists of L4, L8, L12, L16, L32, while for three levels the OA table consists of L9, L18, L27 (Taguchi, 2001).

The number of levels used in the factor is used to select the Orthogonal Array. If the factor is set to level two, then a two-level orthogonal array must be used, and so on. The Orthogonal Array for L4 is shown in the table.

The OA matrix in the table above consists of 3 control parameters (A, B, and C) with two levels (1 and 2). For this matrix, 4 trials are required because based on the Orthogonal Array matrix there are 4 types of combinations.

| Experiment Number | Column 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 |
| 3 | 2 | 1 | 2 |
| 4 | 2 | 2 | 1 |

Figure 6. Orthogonal Matrix Array L4

The OA matrix in the table above consists of 3 control parameters (A, B, and C) with two levels (1 and 2). For this matrix, 4 trials are required because based on the Orthogonal Array matrix, there are 4 types of combinations.

## RESULTS AND DISCUSSION

### Determination and Selection of Orthogonal Array

Orthogonal Array itself can be classified into four types (Park, 1996). Determining the type of OA used can be done by choosing one of the four types of OA that best suits the number of factors and levels studied and also their interactions. The four types of OA are as follows:

1. Orthogonal Array

Standard The standard OA table consists of four types, namely for 2 levels, 3 levels, 4 levels, and 5 levels. For two levels, the OA table consists of $L_4$ $(2^3)$, $L_8$ $(2^7)$, $L_{16}$ $(2^{15})$, $L_{32}$ $(2^{31})$, and $L_{64}$ $(2^{63})$, while for three levels the OA table consists of $L_9$ $(3^4)$, $L_{27}$ $(2^{13})$, $L_{81}$ $(2^{40})$. For 4 levels, the OA table is for example $L_{64}$ $(4^{21})$, and for 5 levels, the example is $L_{25}$ $(5^6)$.

| Experiment Number | Column 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| 3 | 1 | 2 | 2 | 1 | 1 | 2 | 2 |
| 4 | 1 | 2 | 2 | 2 | 2 | 1 | 1 |
| 5 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 6 | 2 | 1 | 2 | 2 | 1 | 2 | 1 |
| 7 | 2 | 2 | 1 | 1 | 2 | 2 | 1 |
| 8 | 2 | 2 | 1 | 2 | 1 | 1 | 2 |

Figure 7. Orthogonal Array L8

2. Extended Orthogonal Array or Partially Orthogonal Array

When there are too many factors to be placed, and interactions can be ignored, the standard OA table can be extended to increase the number of columns to accommodate more factors. Examples are $L_{12}(2^{11})$, and $L_{27}(3^{22})$.

3. *Mixed Orthogonal Array*

This type of OA table contains two different types of levels. This OA is used when there are many factors with different levels, and interactions can be ignored. Examples are $L_{18}(2^1 \times 3^7)$, $L_{32}(2^1 \times 4^9)$, $L_{36}(2^{11} \times 3^{12})$, $L_{36}(2^3 \times 3^{13})$, $L_{50}(2^1 \times 5^{11})$, and $L_{54}(2^1 \times 3^{25})$.

4. *Column-Merged Orthogonal Array*

This OA table is formed from the standard OA table using the column-merged method. Examples are $L_8(4^1 \times 2^4)$, $L_{16}(4^1 \times 2^{12})$, $L_{16}(4^2 \times 2^9)$, $L_{16}(4^4 \times 2^3)$, $L_{16}(4^5)$, and $L_{16}(8^1 \times 2^8)$.

**NOMENCLATURE OF ARRAYS**

$L_a(b^c)$

L - Latin square
a - no of rows
b - no of levels
c - no of columns (Factors)
Degrees of freedom- a-1

| 2-level series | 3 -level series | 4 -level series | Mixed -level |
|---|---|---|---|
| $L_4(2^3)$ | $L_9(3^4)$ | $L_{15}(4^5)$ | *$L_{18}(2^1,3^7)$ |
| $L_8(2^7)$ | $L_{27}(3^{13})$ | $L_{64}(4^{21})$ | $L_{36}(2^{11},3^{12})$ |
| **$L_{12}(2^{11})$ | $L_{81}(3^{40})$ | - | or |
| $L_{16}(2^{15})$ | - | - | $L_{36}(2^3,3^{13})$ |
| $L_{32}(2^{31})$ | - | - | - |

*Interactions cannot be studied

**Can study 1 interaction between the 2-level factor and one 3-level factor

Figure 8. Nomenclature of Arrays

Taguchi matrix is mathematically identical to Hardmard matrix, only the columns and rows are arranged again. The advantage of Orthogonal Array is its ability to evaluate several factors with a minimum number of trials. If in the experiment there are 7 factors with level 2, then using full factorial will require 27 trials. With Orthogonal Array, the number of trials that need to be done can be reduced so that it will reduce the time and cost of the experiment. Orthogonal Array Taguchi method has provided various OA matrices for testing factors with 2 and 3 levels with the possibility of multiple level testing (Ross, 1989).

- Taguchi telah menyusun OA standar

**Common Orthogonal Arrays**

$L_4(2^3)$, $L_8(2^7)$, $L_{12}(2^{11})$, $L_{16}(2^{15})$, $L_{32}(2^{31})$, .. ==> (2-level arrays)

$L_9(3^4)$, $L_{18}(2^1\,3^7)$, $L_{27}(3^{13})$ . . ==> (3-level arrays)

$L_{16}(4^5)$, $L_{32}(2^1\,4^9)$, .. ==> (4-level arrays)

Note: Arrays $L_{18}(2^1\,3^7)$, $L_{32}(2^1\,4^9)$, and $L_{54}(2^1\,3^{25})$ are for mixed level factors.

Figure 9. Common Orthogonal Arrays

| All Combinations for Three Variables of Three Levels Each | | | |
|---|---|---|---|
| | A | B | C |
| 1 | Red | Red | Red |
| 2 | Red | Red | Green |
| 3 | Red | Red | Blue |
| 4 | Red | Green | Red |
| 5 | Red | Green | Green |
| 6 | Red | Green | Blue |
| 7 | Red | Blue | Red |
| 8 | Red | Blue | Green |
| 9 | Red | Blue | Blue |
| 10 | Blue | Red | Red |
| 11 | Blue | Red | Green |
| 12 | Blue | Red | Blue |
| 13 | Blue | Green | Red |
| 14 | Blue | Green | Green |
| 15 | Blue | Green | Blue |
| 16 | Blue | Blue | Red |
| 17 | Blue | Blue | Green |
| 18 | Blue | Blue | Blue |
| 19 | Green | Red | Red |
| 20 | Green | Red | Green |
| 21 | Green | Red | Blue |
| 22 | Green | Green | Red |
| 23 | Green | Green | Green |
| 24 | Green | Green | Blue |
| 25 | Green | Blue | Red |
| 26 | Green | Blue | Green |
| 27 | Green | Blue | Blue |

Orthogonal matrix is a fractional factorial matrix that ensures a balanced comparison of levels in each factor or interaction of factors (Park, 1996). This matrix is used to specify samples from groups. The matrix allows us to determine the specification group during the sample production. Determination of the Orthogonal Array matrix is based on the number of factors and levels used for the study.

| All-Pairs Array, Three Variables of Three Levels Each | | | |
|---|---|---|---|
| | A | B | C |
| 2 | Red | Red | Green |
| 4 | Red | Green | Red |
| 9 | Red | Blue | Blue |
| 12 | Blue | Red | Blue |
| 14 | Blue | Green | Green |
| 16 | Blue | Blue | Red |
| 19 | Green | Red | Red |
| 24 | Green | Green | Blue |
| 26 | Green | Blue | Green |

**Simple Example of Using Orthogonal Array**

The example given here will be very easy to understand because it is related to daily business activities, namely when you want to sell ice cream and are conducting research on how to make delicious, soft ice cream at a low cost, so that later our products will be liked by our customers. After considering it, it turns out that the suggestions after consulting with culinary experts, it turns out that the following ingredients are needed:

1. 2 cans of white sweetened condensed milk
2. 4 cans of liquid milk
3. 2 tablespoons of cornstarch
4. 2 egg whites
5. 2 tablespoons of granulated sugar
6. 1 teaspoon of vanilla

However, after practicing, it turns out that the results obtained are not very tasty and not satisfying. Because we want to be serious in this ice cream sales business, so the entrepreneur-engineer soul wants to try how to find delicious ice cream. The only way is to experiment with a combination of ingredients and the process of making ice cream to make it tastier, not only tastier but still at a low cost. Then an experiment was conducted with a combination test as follows:

1. White sweetened condensed milk: 1 can, 2 cans and 3 cans
2. Liquid Milk: 2, cans, 4 cans and 6 cans
3. Cornstarch: 1 tbsp, 2 tbsp and 3 tbsp
4. Egg White: 1, 2, 3
5. Granulated Sugar: 2 tbsp, 4 tbsp
6. Vanilla: 1 tsp, 2 tsp

The research to design a combination of various choices is a research in the field of Design of Experiments (DoE). Where in the example above, there are 6 factors, namely (1) white sweetened condensed milk, (2) liquid milk, (3) cornstarch, (4) egg white, (5) granulated sugar and (6) vanilla. While each factor has at least 2 levels (choices). Sweetened condensed milk has 3 levels, namely 1, 2 and 3 cans. Liquid milk has 3 levels, cornstarch has 3 levels, egg white has 3 levels, granulated sugar has 2 levels and vanilla has 2 levels.

If we refer to the 'full factorial design', then we will have the number of combinations: 3 x 3 x 3 x 3 x 2 x 2 = 324 combinations. If we think the number 324 is too much, we can take only 1/3 or 1/2 of it. This method is known as 'fractional factorial design'. Of course, after designing the experiment and executing it, data processing and analysis need to refer to the DoE rules.

However, because the combination of experiments and research kits requires large capital, it cannot accommodate that many experiments. Maybe at most we can only try 20 experiments. This is where the concept of 'orthogonal array' (OA) and 'optimal design' (OD) are used. Because OA has unique characteristics and is very useful in designing experiments. OA requires that the combination of levels of several factors must appear in the same amount. If this is not possible, then you can switch to NOA (nearly orthogonal array) and optimal design. These two terms are similar. That is, to aim to imitate 'OA'.

Back to the ice cream example, it turns out that the ice cream problem can be solved with (N)OA. To use it, we need to follow these steps:

1. Enter data on the number of factors, the number of runs (experiments) and the number of iterations in the 'General_Data' worksheet
2. Enter the number of levels and variables to be tested in the 'Variable_Data' worksheet
3. Run the algorithm by clicking 'RUN ALGORITHM' in the 'General_Data' worksheet.

After waiting for about 1.5 minutes, the ice cream making experiment with 18 runs was obtained:

| | Factor_1 | Factor_2 | Factor_3 | Factor_4 | Factor_5 | Factor_6 |
|---|---|---|---|---|---|---|
| Run_1 | 1 | 1 | 0 | 1 | -1 | -1 |
| Run_2 | -1 | -1 | 1 | -1 | -1 | 1 |
| Run_3 | -1 | 0 | 0 | 0 | 1 | -1 |
| Run_4 | 0 | 0 | -1 | 1 | -1 | 1 |
| Run_5 | 1 | 1 | 1 | -1 | 1 | -1 |
| Run_6 | 0 | 1 | 0 | 0 | -1 | 1 |
| Run_7 | 1 | -1 | -1 | 1 | -1 | -1 |
| Run_8 | 1 | 0 | 0 | -1 | 1 | 1 |
| Run_9 | 0 | -1 | 1 | 0 | 1 | -1 |
| Run_10 | -1 | 1 | 1 | 1 | 1 | 1 |
| Run_11 | -1 | 0 | -1 | -1 | -1 | -1 |
| Run_12 | 1 | 0 | 1 | 0 | -1 | 1 |
| Run_13 | 0 | 0 | 1 | 1 | 1 | -1 |
| Run_14 | 0 | 1 | -1 | -1 | 1 | 1 |
| Run_15 | -1 | 1 | -1 | 0 | -1 | -1 |
| Run_16 | -1 | -1 | 0 | 1 | 1 | 1 |
| Run_17 | 0 | -1 | 0 | -1 | -1 | -1 |
| Run_18 | 1 | -1 | -1 | 0 | 1 | 1 |

If we translate the experimental design table with the ice cream example above, then we need to carry out the following experiment:

| No | Susu kental | Susu cair | Maizena | Putih telur | Gula | Vanili |
|---|---|---|---|---|---|---|
| Run_1 | 3 kaleng | 6 kaleng | 2 sdm | 3 butir | 2 sdm | 1 sdt |
| Run_2 | 1 kaleng | 2 kaleng | 3 sdm | 1 butir | 2 sdm | 2 sdt |
| Run_3 | 1 kaleng | 4 kaleng | 2 sdm | 2 butir | 4 sdm | 1 sdt |
| Run_4 | 2 kaleng | 4 kaleng | 1 sdm | 3 butir | 2 sdm | 2 sdt |
| Run_5 | 3 kaleng | 6 kaleng | 3 sdm | 1 butir | 4 sdm | 1 sdt |
| Run_6 | 2 kaleng | 6 kaleng | 2 sdm | 2 butir | 2 sdm | 2 sdt |
| Run_7 | 3 kaleng | 2 kaleng | 1 sdm | 3 butir | 2 sdm | 1 sdt |
| Run_8 | 3 kaleng | 4 kaleng | 2 sdm | 1 butir | 4 sdm | 2 sdt |
| Run_9 | 2 kaleng | 2 kaleng | 3 sdm | 2 butir | 4 sdm | 1 sdt |
| Run_10 | 1 kaleng | 6 kaleng | 3 sdm | 3 butir | 4 sdm | 2 sdt |
| Run_11 | 1 kaleng | 4 kaleng | 1 sdm | 1 butir | 2 sdm | 1 sdt |
| Run_12 | 3 kaleng | 4 kaleng | 3 sdm | 2 butir | 2 sdm | 2 sdt |
| Run_13 | 2 kaleng | 4 kaleng | 3 sdm | 3 butir | 4 sdm | 1 sdt |
| Run_14 | 2 kaleng | 6 kaleng | 1 sdm | 1 butir | 4 sdm | 2 sdt |
| Run_15 | 1 kaleng | 6 kaleng | 1 sdm | 2 butir | 2 sdm | 1 sdt |
| Run_16 | 1 kaleng | 2 kaleng | 2 sdm | 3 butir | 4 sdm | 2 sdt |
| Run_17 | 2 kaleng | 2 kaleng | 2 sdm | 1 butir | 2 sdm | 1 sdt |
| Run_18 | 3 kaleng | 2 kaleng | 1 sdm | 2 butir | 4 sdm | 2 sdt |

The table above is very interesting. It is clearer if we sort it based on the factors of condensed milk and liquid milk as in the table below. Note that the combination of condensed milk and liquid milk each appears exactly twice. This property can also be observed if we sort it based on other factors.

| No | Susu kental | Susu cair | Maizena | Putih telur | Gula | Vanili |
|---|---|---|---|---|---|---|
| Run_16 | 1 kaleng | 2 kaleng | 2 sdm | 3 butir | 4 sdm | 2 sdt |
| Run_2 | 1 kaleng | 2 kaleng | 3 sdm | 1 butir | 2 sdm | 2 sdt |
| Run_11 | 1 kaleng | 4 kaleng | 1 sdm | 1 butir | 2 sdm | 1 sdt |
| Run_3 | 1 kaleng | 4 kaleng | 2 sdm | 2 butir | 4 sdm | 1 sdt |
| Run_15 | 1 kaleng | 6 kaleng | 1 sdm | 2 butir | 2 sdm | 1 sdt |
| Run_10 | 1 kaleng | 6 kaleng | 3 sdm | 3 butir | 4 sdm | 2 sdt |
| Run_17 | 2 kaleng | 2 kaleng | 2 sdm | 1 butir | 2 sdm | 1 sdt |
| Run_9 | 2 kaleng | 2 kaleng | 3 sdm | 2 butir | 4 sdm | 1 sdt |
| Run_4 | 2 kaleng | 4 kaleng | 1 sdm | 3 butir | 2 sdm | 2 sdt |
| Run_13 | 2 kaleng | 4 kaleng | 3 sdm | 3 butir | 4 sdm | 1 sdt |
| Run_14 | 2 kaleng | 6 kaleng | 1 sdm | 1 butir | 4 sdm | 2 sdt |
| Run_6 | 2 kaleng | 6 kaleng | 2 sdm | 2 butir | 2 sdm | 2 sdt |
| Run_7 | 3 kaleng | 2 kaleng | 1 sdm | 3 butir | 2 sdm | 1 sdt |
| Run_18 | 3 kaleng | 2 kaleng | 1 sdm | 2 butir | 4 sdm | 2 sdt |
| Run_8 | 3 kaleng | 4 kaleng | 2 sdm | 1 butir | 4 sdm | 2 sdt |
| Run_12 | 3 kaleng | 4 kaleng | 3 sdm | 2 butir | 2 sdm | 2 sdt |
| Run_1 | 3 kaleng | 6 kaleng | 2 sdm | 3 butir | 2 sdm | 1 sdt |
| Run_5 | 3 kaleng | 6 kaleng | 3 sdm | 1 butir | 4 sdm | 1 sdt |

The OA template is built using iterations to find good solutions. Iterations can be viewed as a measure of the computational effort expended to obtain OA. So the larger the iteration, the longer the computation time and the better the iteration results (usually). The number of runs is 18 because of constraints, such as budget constraints, material and others. In addition, the number of runs must be greater than the number of variables to be analyzed, for example analyzed in linear regression. The number is also attempted as a multiple of the number of levels of the factors so that the number of experiments is balanced.

**Discussion of The Review of the Research Journal Titled Orthogonal Array Testing Strategy (OATS) Technique in the Field of Marketing**

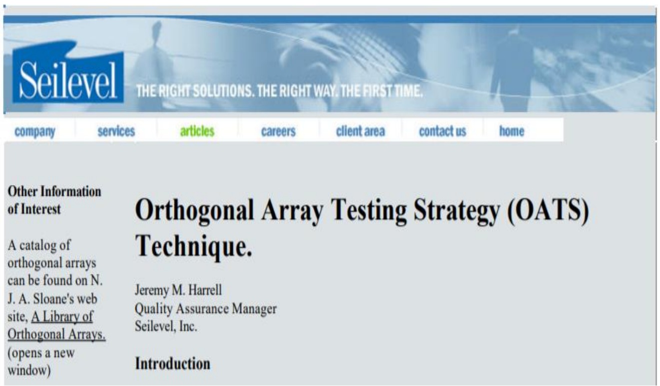


Figure 10. Seilevel Journal

This journal discusses research that wants to be done to see how to create a website page to promote a product, both goods and services. Where this research wants to see how user interaction on the website. So, it is made in the following system:

1. There are three independent variables (page sections).
2. Each variable can take two values (hidden or visible).
3. The orthogonal array $L_4$ ($2^3$) will do the trick - two levels for values and three factors for variables. Note that the number of processes is not necessary to select the appropriate array.
4. Mapping values to arrays will look like Figure 2 where Hidden = 0 and Visible = 1.

**Figure 2**

| OA before mapping factors | | | |
|---|---|---|---|
| | Factor 1 | Factor 2 | Factor 3 |
| Run 1 | 0 | 0 | 0 |
| Run 2 | 0 | 1 | 1 |
| Run 3 | 1 | 0 | 1 |
| Run 4 | 1 | 1 | 0 |

| OA after mapping factors | | | |
|---|---|---|---|
| | Top | Middle | Bottom |
| Test 1 | Hidden | Hidden | Hidden |
| Test 2 | Hidden | Visible | Visible |
| Test 3 | Visible | Hidden | Visible |
| Test 4 | Visible | Visible | Hidden |

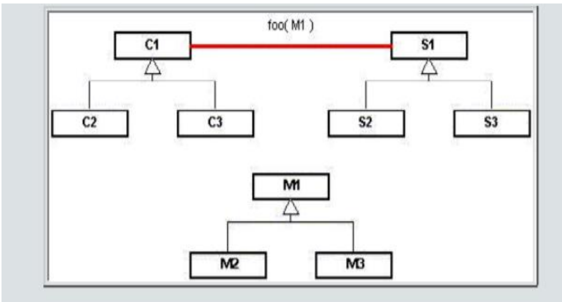
5. Take the test case values from each run, with four test cases. That is all it takes to test all pair-wise interactions between the three variables.

A. Show the website homepage and hide all sections.
B. Show the website homepage and show all but the Top section.
C. Show the website homepage and show all but the Middle section.
D. Show the website homepage and show all but the Bottom section.

Note that not all possible combinations are tested. It takes eight test cases to test all combinations.

An Example That Doesn't Fit with Orthogonal Arrays

Let's look at an example that doesn't fit with the available arrays. This example considers an object-oriented system that contains a client class (C1) with two subclasses (C2 and C3). These client classes interact with a server class hierarchy consisting of a class S1 with subclasses S2 and S3. The server class contains a method foo () that takes an instance of class M1 as a parameter. M1 has two subclasses, M2 and M3. Figure below illustrates the classes involved.




To test all combinations of classes involved, we need 27 test cases (three clients that can each send three messages to three servers - 3 x 3 x 3 = 27). That doesn't seem like much, but it assumes that the foo () method can be tested with just one test case. In most cases, many test cases are needed to test a particular method. Also, these interactions may be a very small part of the overall system being tested. Using OATS techniques can significantly reduce the number of test cases.

1. There are three independent variables (client, server, and message class).
2. Each variable can take three values.
3. Ideally, we would use an array that contains three levels and three factors (an L? ($3^3$) OA). However, there is no such array published. Therefore, we need to find the smallest array

that will handle our problem. The orthogonal $L_9(3^4)$ will work. It has three levels for the values and four factors which is more than enough for three variables.

4. Mapping the values to the array will look like Figure 4 where:
1. For Client, C1 = 0; C2 = 1; C3 = 2.
2. For Server, S1 = 0; S2 = 1; S3 = 2.
3. For Message, M1 = 0; M2 = 1; M3 = 2.

**Figure 4**

OA before mapping factors

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Run 1 | 0 | 0 | 0 | 0 |
| Run 2 | 0 | 1 | 1 | 2 |
| Run 3 | 0 | 2 | 2 | 1 |
| Run 4 | 1 | 0 | 1 | 1 |
| Run 5 | 1 | 1 | 2 | 0 |
| Run 6 | 1 | 2 | 0 | 2 |
| Run 7 | 2 | 0 | 2 | 2 |
| Run 8 | 2 | 1 | 0 | 1 |
| Run 9 | 2 | 2 | 1 | 0 |

OA after mapping factors

| | Client | Server | Message | |
|---|---|---|---|---|
| Test 1 | C1 | S1 | M1 | |
| Test 2 | C1 | S2 | M2 | |
| Test 3 | C1 | S3 | M3 | |
| Test 4 | C2 | S1 | M2 | |
| Test 5 | C2 | S2 | M3 | |
| Test 6 | C2 | S3 | M1 | |
| Test 7 | C3 | S1 | M3 | |
| Test 8 | C3 | S2 | M1 | |
| Test 9 | C3 | S3 | M2 | |

5. There are no “leftover” Levels. However, it appears that there is an additional Factor in the original array. This Factor can be simply ignored; it does not change the properties of the test set generated from the array. You still get an even distribution of pairwise combinations.
6. Taking the test case values from each run, you end up with nine test cases. As mentioned earlier, these nine combinations can map to a larger set of test cases that must be executed against each of the nine combinations.

Here is a more complex example that introduces the concept of mixed-level orthogonal arrays. Let's say we have a system with 5 independent variables (A, B, C, D, and E). Variables A and B each have two possible values (A1-2 and B1-2). Variables C and D each have three possible values (C1-3 and D1-3). Variable E has six possible values (E1-6). To test all possible combinations, a test set containing 216 test cases is required (2 x 2 x 3 x 3 x 6 = 216). There are five independent variables.

1. Two variables can take on two values. Two variables can take on three values. One variable can take on six values.
2. The easiest way to find a suitable OA is to go into your array catalog and look for an array that has at least six levels (the maximum levels for any of our variables) and at least five factors. The smallest orthogonal array with a consistent number of levels that you will probably find is $L_{49}(7^8)$ OA. This array will produce a test set of 49 tests. That is much better than 216, but it is still a lot of tests.
3. You may have noticed the phrase "consistent number of levels" in the previous paragraph. This is important because there happen to be some orthogonal arrays that have varying numbers of levels. One such array is $L_{18}(3^6 6^1)$ OA. The naming of this array means that there are 18 runs for 7 factors, 6 of which contain 3 levels and 1 of which contains 6 levels. Our problem happens to fit this array, and the test set goes from 49 with the first array we identified down to 18. Now that is much better than 216 tests!

4. Mapping the values to the arrays would look something like Figure 5 where:
1. For A, A1 = 0; A2 = 1.
2. For B, B1 = 0; B2 = 1.
3. For C, C1 = 0; C2 = 1; C3 = 2.
4. For D, D1 = 0; D2 = 1; D3 = 2.
5. For E, E1 = 0; E2 = 1; E3 = 2; E4 = 3; E5 = 4; E6 = 5.

**Figure 5**

OA before mapping factors

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 |
|---|---|---|---|---|---|---|---|
| Run 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Run 2 | 0 | 1 | 2 | 2 | 0 | 1 | 1 |
| Run 3 | 0 | 2 | 1 | 2 | 1 | 0 | 2 |
| Run 4 | 0 | 1 | 1 | 0 | 2 | 2 | 3 |
| Run 5 | 0 | 2 | 0 | 1 | 2 | 1 | 4 |
| Run 6 | 0 | 0 | 2 | 1 | 1 | 2 | 5 |
| Run 7 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Run 8 | 1 | 2 | 0 | 0 | 1 | 2 | 1 |
| Run 9 | 1 | 0 | 2 | 0 | 2 | 1 | 2 |
| Run 10 | 1 | 2 | 2 | 1 | 0 | 0 | 3 |
| Run 11 | 1 | 0 | 1 | 2 | 0 | 2 | 4 |
| Run 12 | 1 | 1 | 0 | 2 | 2 | 0 | 5 |
| Run 13 | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| Run 14 | 2 | 0 | 1 | 1 | 2 | 0 | 1 |
| Run 15 | 2 | 1 | 0 | 1 | 0 | 2 | 2 |
| Run 16 | 2 | 0 | 0 | 2 | 1 | 1 | 3 |
| Run 17 | 2 | 1 | 2 | 0 | 1 | 0 | 4 |
| Run 18 | 2 | 2 | 1 | 0 | 0 | 1 | 5 |

OA after mapping factors

| | A | B | C | D | | | E |
|---|---|---|---|---|---|---|---|
| Test 1 | $A_1$ | $B_1$ | $C_1$ | $D_1$ | | | $E_1$ |
| Test 2 | $A_1$ | $B_2$ | $C_3$ | $D_3$ | | | $E_2$ |
| Test 3 | $A_1$ | 2 | $C_2$ | $D_3$ | | | $E_3$ |
| Test 4 | $A_1$ | $B_2$ | $C_2$ | $D_1$ | | | $E_4$ |
| Test 5 | $A_1$ | 2 | $C_1$ | $D_2$ | | | $E_5$ |
| Test 6 | $A_1$ | $B_1$ | $C_3$ | $D_2$ | | | $E_6$ |
| Test 7 | $A_2$ | $B_2$ | $C_2$ | $D_2$ | | | $E_1$ |
| Test 8 | $A_2$ | 2 | $C_1$ | $D_1$ | | | $E_2$ |
| Test 9 | $A_2$ | $B_1$ | $C_3$ | $D_1$ | | | $E_3$ |
| Test 10 | $A_2$ | 2 | $C_3$ | $D_2$ | | | $E_4$ |
| Test 11 | $A_2$ | $B_1$ | $C_2$ | $D_3$ | | | $E_5$ |
| Test 12 | $A_2$ | $B_2$ | $C_1$ | $D_3$ | | | $E_6$ |
| Test 13 | 2 | 2 | $C_3$ | $D_3$ | | | $E_1$ |
| Test 14 | 2 | $B_1$ | $C_2$ | $D_2$ | | | $E_2$ |
| Test 15 | 2 | $B_2$ | $C_1$ | $D_2$ | | | $E_3$ |
| Test 16 | 2 | $B_1$ | $C_1$ | $D_3$ | | | $E_4$ |
| Test 17 | 2 | $B_2$ | $C_3$ | $D_1$ | | | $E_5$ |
| Test 18 | 2 | 2 | $C_2$ | $D_1$ | | | $E_6$ |

6. Like the previous example, this array has additional factors that are not needed. They can be safely ignored and are grayed out in Figure 5. This orthogonal array has "leftover" levels. Variables A and B both have three levels defined in the original array, but there are only two possible values for each variable.

In order to have a fully specified test case to run that has left a level, one must provide a value in the cell. The choice of value is generally arbitrary, but it usually makes sense to add as much variation to the test case as possible to allow for the desired chance of helping to find the error (Marick, 1995).

**Figure 6: OA after mapping left over levels**

| | A | B | C | D | | E |
|---|---|---|---|---|---|---|
| Test 1 | $A_1$ | $B_1$ | $C_1$ | $D_1$ | | $E_1$ |
| Test 2 | $A_1$ | $B_2$ | $C_3$ | $D_3$ | | $E_2$ |
| Test 3 | $A_1$ | $B_1$ | $C_2$ | $D_3$ | | $E_3$ |
| Test 4 | $A_1$ | $B_2$ | $C_2$ | $D_1$ | | $E_4$ |
| Test 5 | $A_1$ | $B_2$ | $C_1$ | $D_2$ | | $E_5$ |
| Test 6 | $A_1$ | $B_1$ | $C_3$ | $D_2$ | | $E_6$ |
| Test 7 | $A_2$ | $B_2$ | $C_2$ | $D_2$ | | $E_1$ |
| Test 8 | $A_2$ | $B_1$ | $C_1$ | $D_1$ | | $E_2$ |
| Test 9 | $A_2$ | $B_1$ | $C_3$ | $D_1$ | | $E_3$ |
| Test 10 | $A_2$ | $B_2$ | $C_3$ | $D_2$ | | $E_4$ |
| Test 11 | $A_2$ | $B_1$ | $C_2$ | $D_3$ | | $E_5$ |
| Test 12 | $A_2$ | $B_2$ | $C_1$ | $D_3$ | | $E_6$ |
| Test 13 | $A_1$ | $B_1$ | $C_3$ | $D_3$ | | $E_1$ |
| Test 14 | $A_2$ | $B_1$ | $C_2$ | $D_2$ | | $E_2$ |
| Test 15 | $A_1$ | $B_2$ | $C_1$ | $D_2$ | | $E_3$ |
| Test 16 | $A_2$ | $B_1$ | $C_1$ | $D_3$ | | $E_4$ |
| Test 17 | $A_1$ | $B_2$ | $C_3$ | $D_1$ | | $E_5$ |
| Test 18 | $A_2$ | $B_2$ | $C_2$ | $D_1$ | | $E_6$ |

7. As mentioned earlier, you end up with 18 test sets out of 216 possible. These 18 test sets will test all possible combinations of pairs of independent variables. This represents a significant saving in testing effort over the all-combination approach, and with this model in place, it will be able to point out tests that should not be done and will find most of the defects in the interactions.

**Criticism on the Journal**

1. In this reviewed journal, the results and further calculations of the experimental design are not presented in detail.
2. This study does not provide information on the results of the industry or published research regarding its costs.
3. There is no information on the effectiveness of using this technique for testing that has been carried out, while in the orthogonal array the aim is to inform about effectiveness.
4. Further research is expected to highlight the need for empirical research like this, so that the OATS technique itself can be continued properly and compared with other experimental design techniques.

## CONCLUSION

It has been stated previously that for research conducting experimental design in the field of marketing is very rare to find and this is also experienced by the author in carrying out this task. And the discussion of the orthogonal array method attracts the author's attention because it is not a common thing to do in the field of marketing so that it increases the desire to be able to study it more seriously.

Orthogonal arrays are used to design efficient experiments and analyze experimental data by using only part of the total conditions so that in this case minimizing the number of experiments, where the number of experiments will be able to provide as much information as possible about the influencing factors. In this discussion, it will also be discussed how to use

Orthogonal Array in research on industrial products.

The use of experimental design that continues to develop will later be very useful in the field of marketing to see how a product is desired by consumers and can make the resulting product better and can save costs so that the use of this experimental design research can be used in decision making for the use of a product of goods and services

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