RELIABILITY OF THE INSTRUMENT WITH CRONBACH'S ALPHA AND VALIDATION OF THE HYPOTHESIS BY ANOVA

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Abstract
The objective of this research is to verify the reliability of the instrument used to collect the information, applying Cronbach's Alpha, and the validation of the hypothesis through an Analysis of Variance (ANOVA). Cronbach's Alpha is obtained in Excel. The survey is used with the questions shown in the Check List, applied in a vehicle assembly plant. The instrument used and the validation of the hypothesis are subjects of a research work, referring to the production planning in the vehicle assembler Ciauto Cia. Ltda. specifically for the HAVAL M4 AC 1.5 TM 5P 4X2 Model, where for the verification of the reliability of the instrument used a Cronbach's Alpha of 0.57 was obtained, which indicates that the instrument used has a poor reliability according to the scale in the Cronbach's Reliability table. As for the validation of the hypothesis by applying an ANOVA, a calculated F - Fisher of 28.25 was obtained, compared to a tabulated F - Fisher of 2.996, so the null hypothesis (H0) should be rejected in favor of the alternative hypothesis (Ha).
Keywords: Survey, Reliability, Hypothesis, Instrument, Model.

1. INTRODUCTION

In a research work to develop a statistical model for production planning in a vehicle assembly plant, Lean Manufacturing tools were used in the assembly area for a particular model, Haval M4 AC 1.5 5P 4X2 TM, and a Check List was designed for the collection of information. The reliability of this process was verified through Cronbach's Alpha, and the hypothesis was validated through an Analysis of Variance (ANOVA) (Muyulema, 2017; Castillo & Aguirre, 2018; Escobar, 2019).
Cronbach's Alpha is used to verify the reliability of the instrument used for data collection. This indicator can be obtained by applying the statistical software SPSS, R or Excel, in this case Excel was applied, and the survey is used for determining the level

of acceptance of the people surveyed in the vehicle assembler Ciauto Cia. Ltda. (Santacruz, 2015)

Additionally, the hypothesis is also validated by applying an Analysis of Variance ANOVA. The hypotheses proposed for this study are:

Null Hypothesis (H0): *"The inadequate implementation of Lean Manufacturing tools in the vehicle assembly line in Ciauto Cía. Ltda. does not affect the production planning technique".*

Alternative Hypothesis (Ha): *"The inadequate implementation of Lean Manufacturing tools in the vehicle assembly line in Ciauto Cía. Ltda. affects the production planning technique".*

II. MATERIALS AND METHODS

- **Instruments**

It establishes the information collection instrument of the initial evaluation questionnaire 5'S, and the 7 MUDAS of Lean Manufacturing tools, and the criteria for production planning established in Ciauto Cia. Ltda. (Garcia, 2011) tools, and the criteria for production planning established in Ciauto Cia Ltda. The validation of the data obtained with the instruments used is done through an analysis of data reliability with the "Cronbach's Alpha" technique in a structured Check List, with its instrument in an observation sheet.

- Observation sheets, applied as an instrument of quantitative research that allows to take and record notes or data of the actions carried out, obtaining information in the field research.
- Use technological tools, as well as R, Lingo 19, for obtaining data, and checking the relationship of research variables and subsequently analyzing production planning data in Microsoft Excel.

- **Methodology.**
- **Cronbach's Alpha calculation**

For the calculation of Cronbach's Alpha, Table 5 show the variance of each item and the total variance for a K=3, and applying the formula (1).

$$\propto = \frac{K}{K-1} * \left[1 - \frac{\sum V_i}{V_t}\right] \quad (1)$$

Where:

$\propto$ (Alfa)

K(Number of items)

V_i(Variance of each item)

V_t(*Total Variance*)

To evaluate Cronbach's alpha coefficients, the following general criteria are considered. (Santacruz, 2015)

- **Cronbach's Alpha Scale**
- Coefficient alpha >.9 is excellent.

- Coefficient alpha >.8 is good
- Coefficient alpha >.7 is acceptable.
- Coefficient alpha >.6 is questionable.
- Coefficient alpha >.5 is poor
- Coefficient alpha <.5 is unacceptable.

- **Diagnosis of the current processes of the vehicle assembly area.**

The reference level taken to identify if the inadequate implementation of Lean Manufacturing tools in the assembly line of Ciauto Cia Ltda., affects the production planning technique, is provided by a *diagnostic Check List* technique, taking into consideration the integrated evaluation ISO 9001:2015, which provides three evaluation scales:

C =Compliance
C/P= Partial Compliance
NC= Non-Compliance

Subsequently, an analysis was carried out for each of the questions that make up the diagnostic *Check List*, and the proportion of the results with respect to the totality of the points evaluated was taken into account for subsequent verification.

For the testing of the hypothesis an analysis of variance was required by means of an ANOVA using a design of experiments with completely randomized blocks where the contrast of the independent variable (Lean Manufacturing Tools) with respect to the dependent variable (production planning) is determined.

A randomized block design is a design often used to minimize the effect of variability when associated with discrete units (e.g., location, operator, plant, lot, time). The usual case is to randomly distribute one replicate of each treatment combination within each block. Generally, there is no intrinsic interest in the blocks, and they are considered to be random factors. The usual assumption is that the block by treatment interaction is zero, and this interaction becomes the error term. To test for treatment effects we designate the response variable as Block, the terms in the model would then be Block, A, B and A*B. I would also specify Block as the random factor and the treatments are the items. ISO 9001:2015, (Aguado, 2015; Benavides, 2016; Ruiz-Gálvez, 2018). (Montgomery, 2004)

Below is the Check List (table 1), used for the collection of information in the vehicle assembler Ciauto Cia. Ltda, which shows the questions asked to 48 people in the assembly area for the M4 Model.

- **Instrument for data collection (Check List)**

The instrument is provided by a *diagnostic Check List* technique, taking into consideration the ISO 9001:2015 integrated assessment.

Table 1. Diagnostic Checklist - Lean Manufacturing

QUALIFICATION GUIDE - LEAN MANUFACTURING		
Reference: Vehicle assembly area	**Code:** MEP-CCT-02	**Date:** 30/05/2020
Responsible: Eng. Juan Carlos Escobar	**Evaluator:** Ing. José Luis Gavidia	
Area Tested: Assembly		

SITUATIONAL DIAGNOSIS CHECKLIST					
No.	**ITEMS**	**C**	**C/P**	**NC**	**TOTAL**
1	**SELECT**				
1.1	Are there useless things that can get in the way in the work environment?	9	25	14	48
1.2	Are there any tools, hardware, spare parts, jigs, fixtures or similar in the work environment?	18	17	13	48
1.3	Are frequently used objects in the work environment in an orderly location and correctly identified?	13	18	17	48
1.4	Are all cleaning items: rags, brooms, gloves, products in their location and correctly identified?	19	17	12	48
1.5	Is there unused machinery in the work environment?	28	12	8	48
1.6	Are unnecessary items identified as such?	15	26	7	48
	Sum	**102**	**115**	**71**	**288**
2	**ORDER**				
2.1	Are materials and/or tools out of place or missing their assigned place?	4	28	16	48
2.2	Are all available and easily identifiable tools necessary?	18	18	12	48
2.3	Are the materials or semi-finished products differentiated and identified from the final product?	16	21	11	48
2.4	Is there any kind of obstacle near the nearest fire extinguishing element?	22	11	15	48
2.5	Are shelves or other storage areas in the right place and properly identified?	25	5	18	48
2.6	Are the maximum and minimum permissible quantities and the storage format indicated?	31	5	12	48
2.7	Are there lines or other markers to clearly indicate aisles and storage areas?	13	18	17	48
	Sum	**129**	**106**	**101**	**336**
3	**CLEAN**				

3.1	Carefully check the floor, access steps and equipment surroundings! Can you find oil stains, dust or residues?	9	13	26	48
3.2	Are parts of the machines or equipment dirty? Can you find oil stains, dust or residues?	10	17	21	48
3.3	Are parts of the luminaire defective (in whole or in part)?	18	24	6	48
3.4	Are walls, floor and ceiling kept clean, free of debris?	5	17	30	52
3.5	Are cleaning tasks carried out regularly in conjunction with plant maintenance?	18	17	13	48
3.6	Is there a person or team of people responsible for overseeing cleaning operations?	16	21	11	48
3.7	Is the floor and equipment swept and cleaned normally without being told?	33	11	4	48
	Sum	**109**	**120**	**111**	**340**
4	**STANDARDIZE**				
4.1	Do staff know and perform the operation properly?	9	13	26	48
4.2	Is the clothing worn by staff inappropriate or dirty?	11	16	21	48
4.3	Are there rest areas, eating areas and smoking areas?	17	25	6	48
4.4	Do the first 3 S's apply?	5	15	28	48
4.5	Does VISUAL CONTROL apply?	18	18	12	48
4.6	Are standard written procedures in place and actively used?	15	21	12	48
	Sum	**75**	**108**	**105**	**288**
5	**SELF-DISCIPLINE**				
5.1	Is a cleanliness check carried out?	7	13	28	48
5.2	Are audit reports done correctly and in a timely manner?	11	20	17	48
5.3	Do the first four S's apply?	17	23	8	48
5.4	Are the staff aware of the 5'S? Have they received training on them?	5	28	15	48
5.5	Is the 5'S culture applied? Are the principles of sorting, tidiness and cleanliness continuously practiced?	1	18	29	48
5.6	Is the statutory uniform used, as well as the daily protective equipment for the activities carried out?	2	22	24	48
	Sum	**43**	**124**	**121**	**288**
6	**Lean Structure**				

6.1	Does the assembly time meet the scheduled time?	28	13	7	48
6.2	Is there any downtime during the assembly period?	16	25	7	48
6.3	Is the transport between operations delayed?	17	25	6	48
6.4	Are there any operational downtimes?	5	28	15	48
6.5	Is there a VMS of process interaction?	18	17	13	48
6.6	Are there evaluations of maintenance times?	16	21	11	48
6.7	Process flow analysis - bottlenecks?	33	11	4	48
6.8	Is the actual inventory flow kept up to date?	7	33	8	48
6.9	Do you keep the indicators of the number of defectives up to date?	5	31	12	48
6.10	Is production capacity evident?	18	15	15	48
	Sum	**163**	**219**	**98**	**480**
7	**Production Planning**				
7.1	Are there any raw materials, semi-finished products or waste not needed in the working environment?	8	27	13	48
7.2	Do you maintain productivity indicators of the assembly area?	16	18	14	48
7.3	Are productivity and labor related?	14	22	12	48
7.4	Is market demand and production planning related?	20	16	12	48
7.5	Is a SWOT analysis performed as a preliminary input to production planning?	28	12	8	48
7.6	Does the cost of goods manufactured mention the cost of goods manufactured in the demand program?	15	26	7	48
7.7	Does the production planning method contemplate the creation of new products?	14	27	7	48
7.8	In the creation of new products, is idea generation maintained as the baseline of development?	5	31	12	48
7.9	Do you maintain a TQM Total Quality Management model with an assembly line production planning orientation?	18	17	13	48
7.10	Are the variables in the production planning process and the continuous improvement approach kept in check?	15	22	11	48
	Sum	**153**	**218**	**109**	**480**
	TOTAL	**774**	**1010**	**716**	**2500**

Subsequently, an analysis was carried out for each of the questions that make up the diagnostic *Check List*, taking into account the proportion of the results with respect to the totality of the points evaluated, for subsequent verification (Table 2).

Table 2: Contingency matrix of the situational diagnosis

No.	ITEMS	C	CP	NC	TOTAL
1	Select	102	115	71	288
2	Order	129	106	101	336
3	Clean	109	120	111	340
4	Standardize	75	108	105	288
5	Self-discipline	43	124	121	288
6	Lean Structure	163	219	98	480
7	Production Planning	153	218	109	480
	TOTAL	**774**	**1010**	**716**	**2500**

- **Inferential Analysis**

An analysis of variance (ANOVA) tests the hypothesis by contrasting two or more research variables (Gutierrez, 2013) . ANOVA assess the significance of one or more factors by comparing the means of the response variable at different factor levels. The null hypothesis states that all the means of the tested population (factor level means) are equal while the alternative hypothesis states that at least one is different (Ruiz & Cruz, 2016) (Gutierrez, 2013) .

The completely randomized block design of experiments model studies the influence of a treatment factor (Ta) with (I) levels on a variable of interest in the presence of an extraneous variable. When the design is used effectively, the mean square error in the ANOVA table is reduced, and the probability of rejecting the null hypothesis and accepting the alternative hypothesis is evident (Gutierrez, 2013) .

In that sense, an analysis of variance was completed by means of an ANOVA using a design of experiments with completely randomized blocks where the contrast of the independent variable (Lean Manufacturing Tools) with respect to the dependent variable (production planning) is determined, taking as treatments the required points of implementation (items) and as blocks the response options (C, CP and NC) (Gutierrez, 2013) .

- **Hypothesis statement**

– Null Hypothesis (**Ho)**

The inadequate implementation of Lean Manufacturing tools in the vehicle assembly line at Ciauto Cía. Ltda. does not affect the production planning technique.

– Alternative hypothesis (**Ha)**

The inadequate implementation of Lean Manufacturing tools in the vehicle assembly line in Ciauto Cía. Ltda., affects the production planning technique.

- **Hypothesis testing**

For the verification of the hypothesis, an analysis of variance was done by means of an ANOVA (Analysis of Variance) (Table 3), based on a design in complete blocks at random, the same that tries to compare three sources of variability: the factor of treatments, the factor of blocks and the random error. The complete objective refers to the fact that in each block all treatments are tested. Randomization is done within each block. The results established the contrast of the independent variable (Lean Manufacturing Tools) with respect to the dependent variable (production planning), taking as:

- *Treatments.* - the required implementation items such as; Select, Sort, Clean, Standardize, Self-discipline, Lean Structure and Production Planning.

- *Blocks. - The* response options are C (Compliance), PC (Partial Compliance) and NC (Non-Compliance).

- **Decision rule**

  - The **null hypothesis** is accepted if the calculated Fisher value **(Fc)** is **equal to or less** than the tabulated Fisher **(FT).**

  - The **alternative hypothesis** is accepted if the calculated Fisher value **(Fc)** is **equal to or greater** than the tabulated Fisher **(FT).**

In a completely randomized block design, the following statistical model is presented (Montgomery, 2004) :

$$y_e = \mu + r_i + B_j + E_{ij} \quad (2)$$

Where:

μ: Overall average

r_iTreatment effect

B_jBlock effect

E_{ij}: Effect of the i-th error (ij)

The Hypothesis testing model by a completely randomized block design is summarized in Table 3:

Table 3: Completely randomized block design model.

Fuente de variación	*Suma de cuadrados*	*Grados de libertad*	*Cuadrado medio (MS)*	F_0	F_0 *Critica*
Tratamientos	$SS_{Tratamientos}$	***a-1***	$\frac{SS_{Tratamientos}}{a-1}$	$\frac{MS_{Tratamientos}}{MS_E}$	***Tabla F al 5%***
Bloque	SS_{Bloque}	***b-1***	$\frac{SS_{Bloque}}{b-1}$		
Error	SS_E	***(a-1) (b-1)***	$\frac{SS_E}{(a-1)(b-1)}$		
Total	SS_T	***N-1***			

Source: Montgomery (2004)

The formula for the respective sum of squares and mean square calculation are shown below (Montgomery, 2004) :

a. Sum of total squares

$$SS_T = \sum_{i=1}^{a}\sum_{j=1}^{b} Y_{ij}^2 - \frac{y^2}{N} \quad (3)$$

b. Treatment sum of squares

$$SS_{Tratamientos} = \frac{1}{b}\sum_{i=1}^{a} Y_i^2 - \frac{y^2}{N} \quad (4)$$

c. Sum of squares of the blocks

$$SS_{Bloques} = \frac{1}{a}\sum_{i=1}^{a} Y_j^2 - \frac{y^2}{N} \quad (5)$$

d. Sum of squares of the error

$$SS_E = SS_T - SS_{Tratamiento} - SS_{Bloques} \quad (6)$$

III. RESULTS AND DISCUSSION

Table 4 presents the number of cases, i.e., the number of people who have completed the survey, in this case, 48 responses of people to be analyzed.

Table 4: Population of the vehicle assembly process Ciauto Cía. Ltda.

Personal	*Frequency*	*Percentage*
Assembly coordination	***1***	***2,1%***
Assembly Supervisor	***1***	***2,1%***
Quality Coordinator	***1***	***2,1%***
Quality assistant	***1***	***2,1%***
Assembly operators	***44***	***91,6%***
Total	***48***	***100.00%***

Table 5 shows the data for the calculation of Cronbach's alpha, where the variance for the response blocks (columns), C, CP and NC, the variance of the total of the items, for a K= 3, is shown.

Table 5: Reliability statistics with Cronbach's Alpha

Items	C	CP	NC	Total
Select	102	115	71	288
Order	129	106	101	336
Clean	109	120	111	340
Standardize	75	108	105	288
Self-discipline	43	124	121	288
Lean Structure	163	219	98	480
Planning Production	153	218	109	480
Variance	1542,244898	2236,77551	211,061224	Vt

From Table 5, the general Cronbach's Alpha is determined, taking into account all the questions, and applying the formula one (1), where the value of this indicator is equal to 0.574, being a poor value according to the scale, to improve this indicator should be added items (treatments) and response options.
Then, applying Table 3, an ANOVA is applied to validate the hypothesis. The following calculations are done.

a. Sum of total squares

$$SS_T = \sum_{i=1}^{a}\sum_{j=1}^{b} Y_{ij}{}^2 - \frac{y^2}{N}$$

$$SS_T = (102^2 + 115^2 + 71^2 + \cdots 109^2 - \frac{(2{,}500.00)^2}{(3)(7)}$$

$$SS_T = 320{,}706.00 - 297{,}619.05$$

$$SS_T = 23{,}086.95$$

b. Sum of squares of treatments

$$SS_{Tratamientos} = \frac{1}{N_t}\sum_{i=1}^{a} Y_i^2 - \frac{y^2}{N}$$

$$SS_{Tratamientos} = \frac{1}{3}(288^2 + 336^2 + 340^2 + 288^2 + 288^2 + 480^2 + 480^2) - \frac{(2{,}500.00)^2}{(3)(7)}$$

$$SS_{Tratamientos} = 312{,}709.33 - 297{,}619.05$$

$$SS_{Tratamientos} = 15{,}090.29$$

c. Sum of the squares of the blocks

$$SS_{Bloque} = \frac{1}{N_t}\sum_{i=1}^{a} Y_i^2 - \frac{y^2}{N}$$

$$SS_{Bloque} = \frac{1}{7}(774^2 + 1010^2 + 716^2) - \frac{(2{,}500.00)^2}{(3)(7)}$$

$SS_{Bloque} = 304{,}547.43 - 297{,}619.05$
$SS_{Bloque} = 6{,}928.38$

d. Sum of squares of the error

$SS_E = SS_T - SS_{Tratamiento} - SS_{Bloque}$
$SS_E = 23{,}086.95 - 15{,}090.29 - 6{,}928.38$
$SS_E = 1{,}068.29$

The results of the sum of squares and mean squares analysis to determine the calculated F_0or F calculated are summarized in Table 6:

Table 6: ANOVA of calculated Fo determination.

Variation source	Sum of squares	Degrees of Freedom	Mean Square (MS)	F_0
Treatments	15090,29	6,00	2515,05	28,25
Block	6928,38	2,00	3464,19	
Error	1068,29	12,00	89,02	
Total	23086,95	20,00		

For six (6) degrees of freedom of the treatments as numerator and twelve (12) degrees of freedom of the error as denominator, applying the table of critical values of the F distribution with 95 % reliability (α = 0.05), a tabulated F - Fisher of 2.996 is obtained, so the calculated F- (Fc) is > the Tabulated F- Fisher (Ft). From where:

- If calculated **F** $Fc = 28{,}25$ < F from table F$t = 2{,}996$ the null hypothesis (H0) is accepted and the alternative hypothesis (H1) is rejected.
- If **F** calculated F$c = 28{,}25$ > F from table F$t = 2{,}996$table, the null hypothesis (H0) is rejected in favor of the alternative hypothesis (H1).

By virtue of the results observed in the previous table, the value of the F-Fisher statistic calculated is greater than the F-Fisher of the table, so it falls in the rejection zone of the null hypothesis (H0), so the alternative hypothesis (H1) is accepted, which indicates that: *"The inadequate implementation of the Lean Manufacturing tools in the assembly line of vehicles in Ciauto Cia.*

For a Cronbach's Alpha value of 0.57 according to the scale in the table, the instrument applied for the data collection has a poor reliability, which can be improved by increasing the variables, however, the results obtained for this research are acceptable.

For a calculated F - Fisher value equal to 28.25 greater than the tabulated F - Fisher equal to 2.996, α falls in the rejection zone, so the Null Hypothesis is rejected in favor of the Alternative Hypothesis.

IV. CONCLUSIONS

Ortiz (2017) in his research conducted with the aim of developing a mathematical model that fits the production planning of the leather sector in the parish of Quisapincha of the canton Ambato. He concludes that: the research began because it was evidenced an inadequate production planning, then information was collected regarding the variables of study with the use of scientific articles and books of the variables of production planning and mathematical models; with their respective fundamental categories. In addition, in order to collect information with respect to the sector, surveys of current and potential customers were used. Subsequently, a correlation and multiple regression analysis was elaborated. By means of the Anova analysis it was possible to identify the variables with the highest correlation between them: i) control, ii) planning, iii) forecast and iv) production process; obtaining a Cronbach's alpha of 0.770; which helped to conclude that the reliability of the instrument used is good, with a tendency to excellent. Finally, the proposal was established to provide the sector with a mathematical model using the Excel statistical tool Solver to identify the necessary resources per week and the optimal amount to produce in order to maximize profits.

Vargas, Muratalla, & Jiménez, (2018) in the research that aimed to analyze the impact on continuous improvement and optimization of a production system through the implementation of Lean Manufacturing tools, as well as the changes that are generated in different companies through an instrument; concludes that: this is achieved using different methods and research techniques, as is the documentary review of different literature, documentary analysis and data collection. Within the results, tables and figures that show the efficiency of this tool are obtained, which proves its validity through successful cases where it was implemented, as well as relevant information that could be used as a basis in companies that have not opted for its application. Additionally, they expose that within the contributions obtained from the realization of this research project is to easily identify the reasons, advantages and applications of Lean Manufacturing in different companies, in order to make the decision to establish this technique. Some limitations are also considered, such as the time required to obtain results, since at least two years are needed.

Campoverde *et al,* (2019) in their work that studied the supply chain taking as reference the productive sector of tires in Ecuador, through the use of a Mixed Integer Linear Programming model. They concluded that: for the design of a statistical model for the supply chain, it was essential to determine the number of raw materials to be delivered, as well as which suppliers should supply the plant, based on the demand for each product, for which an instrument was designed for the collection of information. Additionally, it should be taken into account that for the design of a model should be raised different scenarios, in an optimistic scenario suggests the expansion of consumption areas because several distribution centers converge in some sectors, the conservative model indicates that the distribution centers are optimal, while the pessimistic scenario requires the installation of more distribution centers. On the other hand, the network design is carried out, where it can be observed the application of the Single Distributor approach, since each distribution center covers certain areas, in this way it is possible to cover the demand of the company in all areas of consumption, avoiding duplication of efforts and resources. The final result of the study can be described as the development of a mathematical model that allows to identify the best composition of the logistics network, analyzing different scenarios.

Quezada *et al,* (2020) in the research that had as objective, to find the allocation of batches for processing in the production lines, which optimize the total processing time, as well as the total delay time. They concluded that: to achieve the objective, solutions are evaluated in a statistical simulator of the production system; the optimization of the objective functions corresponds to the PSO algorithm (Particle Swarm Optimization). The optimization is performed first for each objective function and then for both considering weighted weights. The results show correlation in the values of the objective functions, however, the optimal solution of the objective function 1 is not optimal for the objective function 2 and vice versa. For the development of this research work they use an instrument for data collection.

As it can be observed in the exposed results, in most of the research works instruments are used for data collection, which must be validated, as well as the hypothesis by some method.

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