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RESEARCH ARTICLE OPEN ACCESS

OPTIMIZATION OF THE MANUFACTURING PROCESS OF CARDBOARD PACKAGING WITH FUZZY LOGIC: CASE STUDY COMPANY IN THE INDUSTRIAL POLO OF MANAUS

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ABSTRACT

This study arose from the need to meet the demand for manufacturing LCD monitors with cardboard packaging, with less assembly complexity, substantially reducing the amount of folds in the packaging, due to the use of a large number of collaborators involved in the assembly of standard cardboard boxes. The focus of the work is directly on reducing the amount of box folds, maintaining current factory layouts and complying with basic dimensional requirements, geometry, mechanical strength, and customer acceptance criteria (quality tests). The methods used for the purposes of the research were exploratory and descriptive, having as a research instrument applied in the form of observation and analysis in the various stages of the development of the packaging project, proposing a new approach to the concept of boxes that would meet the needs of the modern production and development needs. In this case, we propose, with Fuzzy logic, to validate the results obtained with the new layouts of boxes, as well as other recommendations relevant to the proposed study, creating subsidies to answer the problem raised.

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INTRODUCTION

With the advent of globalization, the market has been undergoing intense transformations, becoming increasingly restless regarding innovations and reduction of raw material and labor costs, requiring companies to be more creative, agile, flexible and having to adapting to different types of cultures and customer needs is undoubtedly a challenging task for executives around the world, requiring greater efforts to survive in the market. And one of the great challenges of today's society is to produce goods and services at the lowest cost, with the lowest possible environmental impact, with high quality, generating employment and income, reducing the use of natural resources. The packaging is the link between the consumer and the product to be purchased by him, it is necessary that the packaging always present good conditions, a good design, being part of a set of factors that make people notice a certain product so that it is marketed (VIEIRA, 2016). Nowadays, there is an increasing need to produce packaging with less raw material, less assembly complexity, concomitantly with fewer possible folds, however, maintaining the physical integrity of the product, appearance and resistance to the various mechanisms. involved, such as: relative humidity, handling, transport, storage time and stacking pattern (Selke et al., 2016). Identify points of improvement, referring to excess folds in the boxes, and develop changes in the layout aiming at optimization, reducing raw material and labor costs. These changes require quality tests for validation and the use of logic as a validation fact for the new layout.

MATERIALS

Os materiais utilizados no desenvolvimento das novas embalagens com menor quantidade de dobras, usamos softwares de desenvolvimento de embalagens e equipamentos de testes de qualidade conforme informado abaixo:

Tabela 1. Materiais de apoio utilizados no estudo.

Item	Descrição
1	Computador Windows 10 e software GERTARCAD
2	Plotter de recorte de Papel
3	Máquina de drop test (teste de queda)
4	Máquina de teste de Vibração
5	Máquina Prensa de Teste de Compressão
6	Calibre de caixas
7	Computador com Windows 10 com software Matlab instalado para uso da lógica *Fuzzy*

Fonte: Autor (2022).

Metodologia: The objective of this study is the development of a new design of cardboard boxes with a reduction in the number of folds, using Fuzzy logic, to validate the evaluation and decision-making process regarding the approval of the new packaging.

We define it as a sequence of work and study, as follows:

- Identify all LCD monitor packaging, measure the amount of folds per product.
- Define new packaging design considering the reduction of folds during the project.
- Raise the amount of folds of the current monitor boxes and define, together with fuzzy logic, fold values compatible with the functionality of the new box designs.
- Use fuzzy logic as a tool to validate the results obtained, with regard to bending reductions in the project.
- Carry out resistance tests on the new packaging developed, which meet the original design specifications.
- Test new design on production line and compare productivity gains with original packaging.
- Carry out the final quality tests of the new packaging to approve it in the use of the products.

Case Study Application: The study was started, in the premises of a multinational company installed in the industrial pole of Manaus, manufacturers of LCD monitors and with the support of companies that manufacture packaging boxes for electronic products, also installed in the Industrial pole of Manaus. In 2019, with the increase in the production of monitors, and consequently the pressing need for improvements in production processes, which would bring differential and technological solutions, in relation to competitors, aiming at the simplification of products/process. There was a need to optimize monitor packaging projects, which would guarantee acceptance by the end customer, ensured quality and less assembly complexity. We considered the bend lift of all monitor boxes and consolidated the values according to the following table:

Table 2. Sum of Cardboard Box/Shims Folds of LCD Monitors

BOXES/SHIMS TABLE STANDARD FOLDS				
ITEM	MODELS	BOX	CHOCK	
1	AM1	100	200	300
2	AM2	120	238	358
3	AM3	110	232	332
4	AM4	98	224	322
5	AM5	102	220	322
6	AM6	108	246	354
7	AM7	110	242	352
8	AM8	112	252	364
9	AM9	96	246	342
10	AM10	94	240	334
11	AM11	98	244	342
12	AM12	104	248	352

Fonte: Autor (2022).

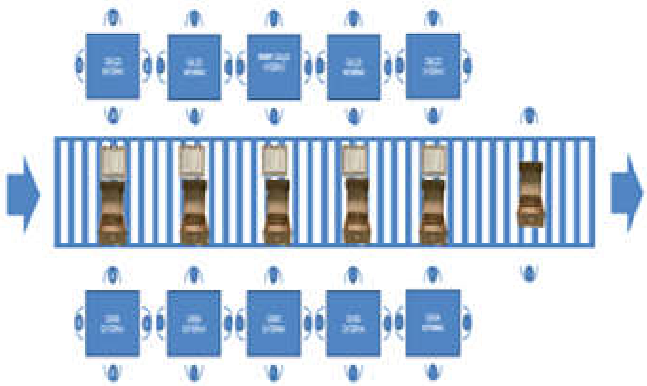
After the initial survey of the folds of boxes of all models of LCD monitors, we verified the average of folds to arrive at a standard value of folds for the beginning of the works:

$$M = \frac{\Sigma}{QMM} = 4074/12 = 339{,}5 \cong 340 \text{ folds}$$

Where

Σ = Sum of the amount of folds in all models of LCD monitor boxes.
QMM = Quantidade de modelos de monitores.

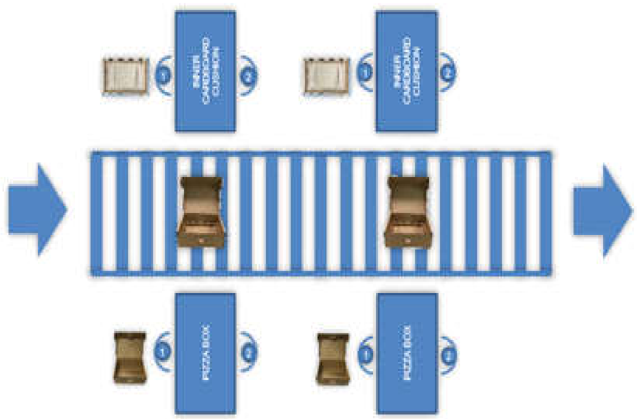
The result tells us the average amount of folds per monitors, where we carry out the analysis of the production process for the survey of necessary manpower and layout for the execution of this activity. The figure below demonstrates the result of the Process Engineering study:



Source: Author (2021).

Figure 1. Production Flow Schematic Diagram of Standard Fold Quantity Boxes

After the study of times and methods prepared by Process Engineering, we observed that the average workforce needed to assemble the packaging was 45 employees, considering an average production line of 51 employees for the assembly of each monitor model , we can say that for each monitor assembly line, we have to have a box assembly line. Considering the amount of labor allocated for the assembly of boxes within the company, which was 08 people (value stipulated considering the standard of labor for the assembly of TV boxes, less complex than the boxes of LCD monitors in the same company), there was a need to reduce the complexity of the boxes, otherwise we would significantly increase the number of operators and layout area and there would be a great loss in the production setup (change from monitor assembly to TV and vice versa). We consider that the project should respect the standard layout for assembling boxes as shown in the photo below:



Source: Author, (2020).

Figure 2. Production Flow Schematic Diagram for assembling TV boxes

The layout shown above, considered standard for assembling TV boxes within the company, considers 08 operators in the assembly of boxes. To respect this standard, there would be a need to modify the design of the LCD boxes, where the bending values would have to be reduced to adapt the boxes to the assembly process. Considering that to achieve the values of "folds x amount of labor x production layout", the number of folds would be needed according to the table below:

$$QD = \frac{QMD}{QPO} = \frac{340}{8} = 42{,}5 \simeq 43$$

Where

QMD = Average amount of creases per LCD monitor.
QPO = Standard number of operators on the packaging line

Considering the production volume factors, differentiated by model, monitor geometry, micro pauses in the process, ergonomic analysis of the SDESMT and quantity of accessory sets (varies according to the model), the maximum value of 50 folds per unit of packing box. Considering values above 42 as disapproved.

Table 3. Criteria for evaluation of bends of the box/shim set

FOLDS	VALUES
APPROVED	13 ~ 36
ACCEPTABLE	36 ~ 42
DISAPPROVED	42 ~50

From the table we created the inference rules for the study of Fuzzy logic.

Table 4. Inference Rules for Bends

Item	CASHIER	SHIM	RESULT
1	Low	Low	Approved
2	Low	Low	Acceptable
3	Low	Medium	Approved
4	Low	Medium	Acceptable
5	Low	High	Disapproved
6	Low	High	Approved
7	Low	Low	Disapproved
8	Low	Medium	Disapproved
9	Low	High	Acceptable
10	Medium	Medium	Acceptable
11	Medium	Low	Acceptable
12	Medium	Medium	Approved
13	Medium	High	Disapproved
14	Medium	High	Acceptable
15	Medium	Medium	Disapproved
16	Medium	Low	Disapproved
17	Medium	High	Approved
18	Medium	Low	Approved
19	High	High	Disapproved
20	High	High	Acceptable
21	High	Medium	Disapproved
22	High	Medium	Acceptable
23	High	High	Approved
24	High	Low	Disapproved
25	High	Low	Approved
26	High	Medium	Acceptable
27	High	Low	Approved

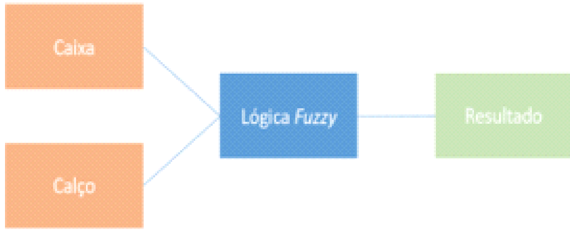
Source: Author, (2021).

Considering the evaluation functions of the input and output variables, the inference ones are assembled according to the formula below:

The equation: R = Nv
R is the number of rules
N is the number of inferences
V is the number of variables

Then:

$R = 3^9$ $R = 27$

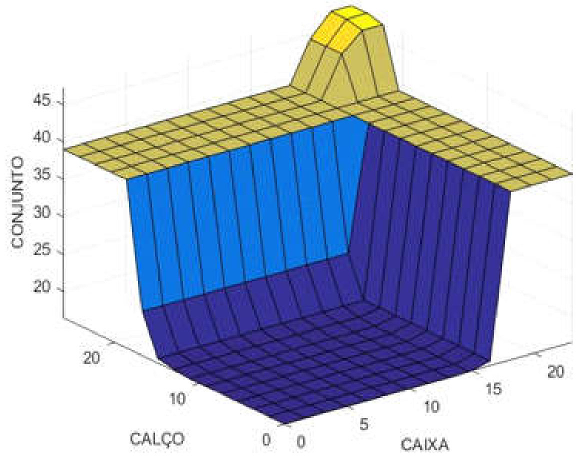


Source: Author, (2020).

Figure 3. Fuzzy System for the evaluation of box folds

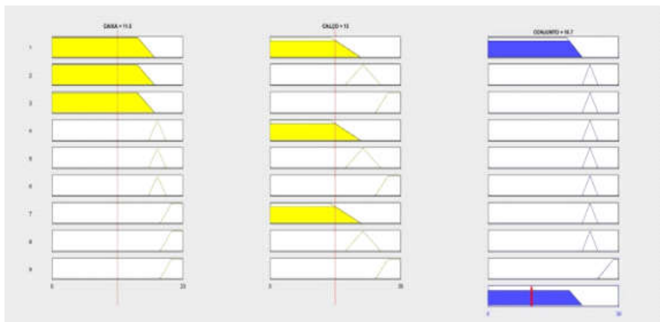
RESULTS AND DISCUSSION

In the study of the results, we can evaluate in figure 3 through fuzzy logic, that by changing the number of folds of the box, to a greater value, we have to compensate for this variation in the box shim, considering that values above 50 folds must be respected during the analysis of the project, avoiding very high values and always making the compensation of the folds as far as possible, in case there are high values in one or another item of the box.



Source: Author, (2021).

Figure 4. Shape of the output variable

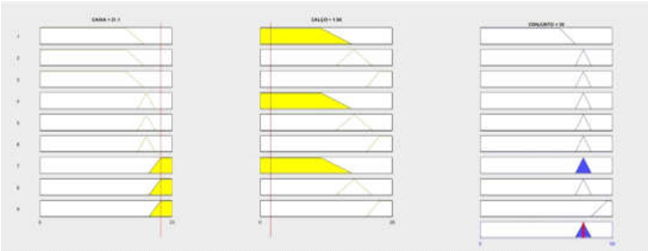


Source: Author, (2021).

Figure 5. Result Fuzzy System Inference Rules

Source: Author, (2021).

Figure 6. Result Fuzzy System Inference Rules



Source: Author, (2021).

Figure 7. Result Fuzzy System Inference Rules

FINAL CONSIDERATIONS

A fuzzy logic approach was proposed to optimize packaging box folds. Minimizing the different types of problems in companies and in any segment is very important, especially when there are tools that allow it, as was verified in the study in question. The work aimed, among others, to present a study of optimization and development of cardboard packaging for LCD monitors, reducing the amount of folds and using Fuzzy logic in the process. Meeting the requirements stipulated by suppliers, internal and external customers considering the manufacture of new cardboard packaging with a new design. It is assumed that the presented study contributes satisfactorily to strategic decision making. The fuzzy system demonstrates great capacity for analysis and evaluation studies of packaging processes, where reducing the amount of folds makes a difference, adding value to the business, reducing labor costs and reducing time with process setup.

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