Intelligent planning and continuous improvement in the hardware industry using AHP and Proportionality.

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Abstract:

Choosing a manufacturing process for the elaboration of technological products, is fundamental, we are talking about that the manufacturing process is the one that in the end will decide the planning of the production lines of these artifacts, it is something that should not be taken lightly, since this depends on the quality of the final product and its product generation. The selection of a smart manufacturing process should give the consumer a high quality product, which surpasses the previous generation in terms of energy efficiency and power.

In Industry 4.0 it is important that the hardware industries remain more competent than ever, as their products are at the end of the day the ones that will be driving the artificial intelligence of other companies, the data centers or the servers of entertainment sites. With that said, we will look to identify the best process for the industry and how to plan production lines so that to ensure that everything is utilized and that each process is better than the last.

Keywords: manufacturing method, architecture, continuous improvement, intelligent planning, industry 4.0, AHP, proportionality,

Introduction:

The hardware industry is one of the most important worldwide, the improvement of the manufacturing processes of these components directly affects the other industries, we can notice, for example, the implementation of sophisticated robot systems based on artificial intelligence in BMW factories, in addition to the use of intelligent data to make intelligent planning systems for the continuous improvement of their automobiles.[1].

The selection of a base architecture on which the silicon circuits will be developed will determine in a highly significant way the number of tasks that the component will be able to perform. The general idea on paper would be very simple, select the most advanced and best manufacturing process, but it is not that simple. We have to start with the basis of the way silicon circuit manufacturing processes are named, they are, since about 1985, obsolete. It is based on Moore's law, which was cited in 1965 and states that approximately every 2 years the number of transistors in a microprocessor would double [2]. Although the fulfillment of the law is still counted to this day, it was in 1985 where Gordon Moore himself proclaimed that from now on the manufacturing processes would be more complex and difficult to make them smaller [3].

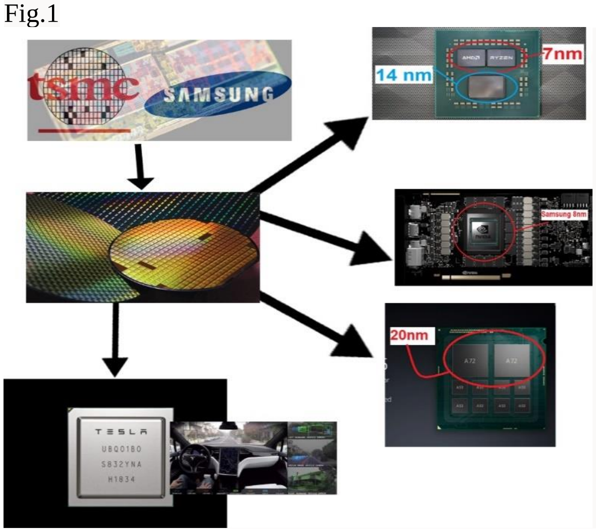
In the world there are 3 companies which are the ones that sell their manufacturing processes to the other companies, which are: TSMC, SAMSUNG and INTEL, the latter of which normally only manufacture for their own processors, although in recent years they have started to work with TSMC in order to improve their own manufacturing processes.

Today, that a process is called "7nm" does not mean that the size of the transistors is 7nm, this has remained more by tradition, for example, an Intel manufacturing process has 10nm, is equivalent to the TSMC manufacturing process of 7nm, it is a standard that was left by Moore's law.

It is very common that the trend is "Choose the best and most expensive manufacturing process to give the highest quality product" but in many cases it can not be so, a company that is dedicated to the development of hardware whether they are: Processors, Graphics Cards, Cellular phones, etc.... must take into account all surrounding possibilities when selecting a manufacturing method. If we are trying to manufacture processors for phones in countries with emerging economies, we need to look for the manufacturing process that allows us to develop a processor that suits the needs of consumers and also does not raise production costs or a situation as simple as for example that an external company has already bought the production of the best and manufacturing process.

At the same time, we must take into account that after selecting the manufacturing process, we have to design the production lines of what we want to produce, the silicon wafers come with their defects and the size of the production depends entirely on how many bad chips we will get, we have to adapt the planning to reuse these defective chips or leftovers to minimize possible losses.

Fig.1



Regarding the image: We will take the technical specifications of each manufacturing method, according to their data sheets, as well as extra data such as cost and country of origin, we will put them in a comparator, this will help us a lot in the decision-making process in the selection of the most optimal manufacturing method, depending on what we are going to use it for. Although in the technology industry we usually select the most refined and technologically advanced processes, there are certain aspects, in which we will be forced to select an older manufacturing process, either by a standard in the costs we want to manage or for other more specific things.

Manufacturing processes are directly affected by who is the main buyer, we can find cases such as in the case of the 5mm manufacturing method, where Apple has bought in advance much of the production of wafers in this method that TSMC produces, all these external factors are the ones we have to see for what we need to manufacture.[4] We can also find problems in the stock of stock of wafers that are not available in the market.

We may also encounter production stock issues that may limit the amount of wafers available for certain manufacturing processes, so in many occasions, companies often select better stocked or cheaper (depends on the situation) manufacturing processes for lower end products and use the better processes for making their better quality, more powerful and more expensive products. Every industry has its priorities, as long as they can serve the best possible product while maintaining an affordable price, targeted to a specific audience, it can work.

Proper use of wafers.

There are products, which simply do not need a complex manufacturing process, as it depends on the product, it could affect the final price of what we want to sell.

In the following table we will see different types of products, developed by different companies in order to appreciate how an intelligent selection of the manufacturing processes matters.

Table 2 - Comparison of different products and their manufacturing methods.

Producto	Fabricante	Proceso	Año
FSD-CHIP	TESLA	14nm Samsung	2019
Ryzen 3gen	AMD	14nm y 7nm TSMC	2019
RTX serie 30	NVIDIA	8nm Samsung	2020
Apple M1	APPLE	5nm TSMC	2020
Snapdragon 850	QUALCOMM	10mm Samsung	2020
Snapdragon 720G	QUALCOMM	8nm Samsung	2020
Intel 11gen	INTEL	10nm++ Intel	2020

As we can see, different products may require different manufacturing processes, although computer processors usually have the best manufacturing processes, other products such as the processors used in Tesla's smart cars may have less advanced manufacturing processes because it would increase the cost for extra power, which is not really needed, or in the case of Qualcomm, which usually has different processors for different ranges, it usually has processors with cheaper older processes, for phone manufacturers who need to adapt lower prices for their public.

Most used manufacturing methods, their shortcomings and priorities for each product].

Wafer fabs, both TSMC and Samsung, have at their disposal to purchase older manufacturing methods for their prospective buyers. This is in order to have a variety, there are products that simply do not need more complex manufacturing processes.

Typically, it is the processors that have the most complex and modern manufacturing methods, being the phone processors, because of the need to cram a larger amount of transistors into smaller devices they usually look for smaller process sizes to achieve a higher quality processor. Computer processors being the most powerful, these look for the best refined manufacturing process rather than the smallest, the manufacturing process at 7nm was launched in 2018, the newest being the manufacturing process has 5nm. But as the 7nm manufacturing process can manage to build more complex architectures, because it has been more refined than the 5nm which is brand new, AMD decided to launch its 4th generation of Ryzen processors with this architecture, because it is the one that allows them to better build their architecture. Apple, on the other hand, selected the 5nm process for the construction of the A14 BIONIC processor, because for a phone, it is the architecture that can present more power for its architecture that seeks lower power consumption while getting the most power possible.

We have already seen that the most used manufacturing method depends on the needs of the moment, however there are many external factors that can make it difficult to select the best manufacturing process. Silicon wafers are not perfect, they come with errors, they come with defective chips, and the larger the manufacturing process, the greater the loss,

II - Methodology.

In this case, we will take the role of a company, which is developing a range of processors for cell phones, aimed at emerging countries. The objective will be to develop a processor that is competent in the market, but at the same time very cheap to produce so that the final price of the phone does not exceed a price of 150 to 250 dollars. So we are looking for the chip to sell for around 50 cents each.

With this we must select a manufacturing method that is modern, allowing us to develop a processor that is competent, for this we have limited the manufacturing processes to 20nm, because using an older one, simply would not do us any good.

The methodology to be used for the selection of the best manufacturing process will be AHP is a structured technique for dealing with complex decisions. Instead of prescribing the correct decision, AHP helps decision makers find the solution that best fits their needs and their understanding of the problem.

This tool, based on mathematics and psychology, was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined ever since. AHP provides a rational and comprehensive framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall objectives, and for evaluating solution alternatives. AHP is used around the world in a wide variety of decision situations, in fields such as government, business, industry, health care, and education.[5] AHP is used in a wide variety of decision situations in fields such as government, business, industry, health care, and education.

The main objective is placed at the first level, sub-criteria and decision alternatives are listed in descending levels of the hierarchy. AHP analyzes the factors involved in the decision process without requiring them to be on a common scale , which makes it one of the most widely used decision techniques for solving socioeconomic problems, as it incorporates, cultural and other non-economic considerations into the decision making process. [6]

Levels of importance are assigned when they are compared and a value is added to them depending on their value within a scale.

Equation 1.

$$S = f(x) = \left\{\frac{1}{9} + \frac{1}{8} + \frac{1}{7} + \frac{1}{6} + \frac{1}{5} + \frac{1}{4} + \frac{1}{3} + 1,2,3,4,5,6,7,8,9\right\}$$

Table 3(7):

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favor one activity over another.
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favor one activity over another.
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice.

Proceso	fabricante	País de origen	Año de fabricación	Costo por olbea	Cant. De chips por oblea	stock	Tamaño de oblea	Densidad de trans.	Litografía
8nm	SAMSUNG	COREA DEL SUR	2018	$6800	1104.46875	Bajo	300mm	61.18(MTr/mm2)	EUV
14nm	TSCM	COREA DEL SUR	2016-2017	$5,992	360.6428571	Bueno	300mm	52.51(MTr/mm2)	293nm
7nm	TSMC	CHINA	2019	$9,000	1442.571429	Bajo	30mm	93~~(MTr/mm2)	EUV
7nm	SAMSUNG	COREA DEL SUR	2019	$9,436.00	1442.571429	Muy Bajo	30mm	95.3(MTr/mm2)	DUV
5nm	TSMC	CHINA	2020	$17,000~~	2827.44	Muy Bajo	300mm	127(MTr/mm2)	EUV
16nm	TSMC	CHINA	2015	$3,984.00	276.1171875	Medio	300mm	28.88(MTr/mm2)	193mm
14nm	SAMSUNG	COREA DEL SUR	2017	$5,500	2827.44	Muy bajo	300mm	32.94(MTr/mm2)	193mm
5nm	Samsung	Corea del sur	2021	$16,988	2827.44	medio	300mm	123(MTr/mm2)	EUV

Table 4.

The order in which the aspects are arranged and the data to be highlighted does not represent anything in terms of the value of each of the criteria.

To make the best decision what we will proceed to do is to compare each one of the aspects of comparison, using table 3 we will apply the 7 point scale, they will be arranged in a table where we will apply the criteria of comparison and we will see its dominance with respect to the other aspects, in the case that element one, has a greater dominance in element 2, its position will have a 5 and the reciprocal position will be 1/5.

Once we have completed our matrix, the problem will be reduced to the calculation of the values to represent the properties of each alternative, using the following formula (8):

Equation 2

$$A * w = \lambda * w$$

Where: A = reciprocal matrix of paired comparisons (judgments of importance/preference of one criterion over another)

λ = Maximum Origin Value of A

w= Eigenvector corresponding to λ

The advantages of using the AHP technique are reported by Beynon (2002) who indicates that there are at least 3 (9):

1. Evaluations in which there are qualitative factors are allowed.

2. Weights are assigned to each of the elements, which are used as criteria for decision making.

3. The use of computers allows for sensitivity analysis of the results.

Thanks to the use of AHP we have the advantage of the hierarchical process of decision making that this provides us, thanks to AHP we can have the advantages that the most important decision factors but difficult to compare, is when AHP enters to solve this problem to solve the way we decide between different alternatives. Among other factors, AHP allows us to detect the consistencies that we have between our decision factors (10) with the incorporation of

IC (Consitency index) y CR (Consitency Relasionship).

Equation 3 & 4

$$IC = \frac{\lambda MAX - n}{n-1}$$

$$RC = \frac{IC}{IA}$$

Criteria to analyze:

The criteria have been analyzed according to how much they affect the final product and what we want to achieve by producing.

- **Country of the manufacturer (PF)**: We will refer to the 2 possible options: South Korea or China, it is important to take into account this consideration, because this will mark small details to consider that can benefit or harm the situation. From the calculation of the carbon footprint to the geopolitical factors within the restrictions of each country and the counter situations that may arise within the opportunities.

- **Stock (S):** the amount of product that the manufacturer is willing to deliver, this is subject to multiple considerations, such as the main buyers of the manufacturer.

- **Year (Y):** This aspect could fall under the power aspect, but we qualify it separately due to the fact that also other aspects such as stock and cost, not only power, we have to take into consideration that a newer manufacturing method, may not support certain architectures planned for certain
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  technological devices because they require research, an older method can facilitate and lower costs because of the experience that the manufacturer already has with this architecture and can offer a more refined manufacturing method. Keep in mind that the newer the manufacturing method, not only more expensive and more powerful, but also requires an extra effort to incorporate it within the industry, a greater learning curve to implement it. For these reasons the year of production is considered apart from the other aspects.

- **Cost (Co):** Our next aspect is to qualify the average cost of each silicon wafer that we need to take into account in order to achieve a considerable net profit to be able to maintain the market. The waste that can generate the amount of defective chips per wafer are accounted for and the capacity of the selected architecture to be used in other ranges and products that can allow continuous improvement in our manufacturing processes.

- **Power (PT**): We will refer to the aspects previously presented in the table, the density of transistors, technical aspects that will allow us to know which is the most powerful method.

In the industry the use of AHP has been very important in recent years to make good decision making, in this case we are using it to compare the most important aspects that gives us each manufacturing process and with this to compare concisely which of its characteristics can demonstrate in a better way, which of the processes is the most complete. These 5 decision factors will be compared in the matrix, therefore, each criterion can be calculated and standardized.

Table 5

CRITERIO	PF	S	Y	Co	PT
PF	1	5	2	6	3
S	1/5	1	3	6	3
Y	½	1/3	1	6	4
Co	1/6	1/6	1/6	1	7
PT	1/3	1/3	1/4	1/7	1
Total	2.20	6.84	6.42	19.14	18

Ahora pasaremos ha establecer el paso de cada criterio al valor final.

Table 6

0.45	0.73	0.32	0.32	0.17	0.398
0.09	0.14	0.47	0.32	0.17	0.238
0.23	0.04	0.16	0.32	0.23	0.196
0.07	0.02	0.03	0.05	0.39	0.112
0.15	0.04	0.04	0.007	0.05	0.0574

Once obtained the weights that each of the criteria has within the selection, with respect to the standardization of the dies.

The following is to calculate the weight of the cost of each of the manufacturing processes, the cost will be compared with the availability of the product, since a low stock, can raise the base cost of the silicon wafer, once the matrix is made, we will take the weights for decision making. All in order to identify which process has the best cost.

Table 7

Criterio	S 5nm	S 7nm	S 8nm	S 14nm	T 5nm	T 7nm	T 14nm	T 16nm
S 5nm	1	5	6	7	1	6	6	7
S 7nm	1/5	1	2	4	7	1	3	3
S 8nm	1/5	1/2	1	4	6	2	3	3
S 14nm	1/7	1/4	1/4	1	7	3	1	2
T 5nm	1	1/7	1/6	1/7	1	5	6	7
T 7nm	1/6	1	1/2	1/3	1/5	1	1	1
T 14nm	1/6	1/3	1/3	1	1/6	1	1	2
T 16nm	1/7	1/3	1/3	1/2	1/7	1	1/2	1
TOTAL	3.02	8.56	10.58	17.98	22.51	20.00	21.50	26.00

Estandarización de la matriz

0.33	0.58	0.57	0.39	0.04	0.30	0.28	0.27	0.35
0.07	0.12	0.19	0.22	0.31	0.05	0.14	0.12	0.15
0.07	0.06	0.09	0.22	0.27	0.10	0.14	0.12	0.13
0.05	0.03	0.02	0.06	0.31	0.15	0.05	0.08	0.09
0.33	0.02	0.02	0.01	0.04	0.25	0.28	0.27	0.15
0.06	0.12	0.05	0.02	0.01	0.05	0.05	0.04	0.05
0.06	0.04	0.03	0.06	0.01	0.05	0.05	0.08	0.05
0.05	0.04	0.03	0.03	0.01	0.05	0.02	0.04	0.03

Table 8

Stock is very important, there are products that have more stock than others because of their main buyers or external situations, it is important to compare them because this affects the price within the planning and can be decisive for the selection of a method.

Criterio	S 5nm	S 7nm	S 8nm	S 14nm	T 5nm	T 7nm	T 14nm	T 16nm
S 5nm	1	3	4	6	1	3	5	6
S 7nm	1/3	1	2	4	2	1	4	5
S 8nm	1/4	1/2	1	3	4	2	5	6
S 14nm	1/6	1/4	1/3	1	5	3	1	3
T 5nm	1	1/2	1/4	1/5	1	3	5	7
T 7nm	1/3	1	1/2	1/3	1/3	1	5	6
T 14nm	1/5	1/4	1/2	1	1/5	1/5	1	2
T 16nm	1/6	1/5	1/5	1/3	1/7	1/6	1/2	1
TOTAL	3.45	6.70	8.78	15.87	13.68	13.37	26.50	36.00

Table 9

The year of production can represent a great advantage in comparison in each of the manufacturing methods.

manufacturing methods, a very old manufacturing year can be very obsolete for the newer ones, but you can have a cleaner process, thanks to the fact that you already have enough experience in certain architecture to deliver a better product with less.

Table 10

0.29	0.45	0.42	0.38	0.07	0.22	0.19	0.17	0.27
0.10	0.15	0.21	0.25	0.15	0.07	0.15	0.14	0.15
0.07	0.07	0.11	0.19	0.29	0.15	0.19	0.17	0.15
0.05	0.04	0.11	0.06	0.37	0.22	0.04	0.08	0.12
0.29	0.07	0.03	0.01	0.07	0.22	0.19	0.19	0.14
0.10	0.15	0.05	0.02	0.02	0.07	0.19	0.17	0.10
0.06	0.04	0.05	0.06	0.01	0.01	0.04	0.06	0.04
0.05	0.03	0.02	0.02	0.01	0.01	0.02	0.03	0.02

Criterio	S 5nm	S 7nm	S 8nm	S 14nm	T 5nm	T 7nm	T 14nm	T 16nm
S 5nm	1	3	3	5	1	3	5	7
S 7nm	1/3	1	2	4	3	2	4	5
S 8nm	1/3	1/2	1	3	3	1	3	3
S 14nm	1/5	1/4	1/3	1	5	3	1	2
T 5nm	1	1/3	1/3	1/5	1	2	3	4
T 7nm	1/3	1/2	1	1/3	1/2	1	3	3
T 14nm	1/5	1/4	1/3	1	1/3	1/3	1	1
T 16nm	1/7	1/5	1/3	1/2	1/4	1/3	1	1
TOTAL	3.54	6.03	8.33	15.03	14.08	12.67	21.00	26.00

Table 11 & 12

0.28	0.50	0.36	0.33	0.07	0.24	0.24	0.27	0.29
0.09	0.17	0.24	0.27	0.21	0.16	0.19	0.19	0.19
0.09	0.08	0.12	0.20	0.21	0.08	0.14	0.12	0.13
0.06	0.04	0.04	0.07	0.36	0.24	0.05	0.08	0.12
0.28	0.06	0.04	0.01	0.07	0.16	0.14	0.15	0.11
0.09	0.08	0.12	0.02	0.04	0.08	0.14	0.12	0.09
0.06	0.04	0.04	0.07	0.02	0.03	0.05	0.04	0.04
0.04	0.03	0.04	0.03	0.02	0.03	0.05	0.04	0.03

The country of the manufacturer is a factor that will not have so much weight, since each one has advantages that the other does not, but considering the global health situation, we can say that South Korea has an extra advantage over China, since China's shipments are still complicated, so South Korea has a small advantage over the Chinese manufacturer.

Table 13

Criterio	S 5nm	S 7nm	S 8nm	S 14nm	T 5nm	T 7nm	T 14nm	T 16nm
S 5nm	1	3	3	7	1	4	5	7
S 7nm	1/3	1	2	4	2	2	3	4
S 8nm	1/3	1/2	1	4	2	2	4	5
S 14nm	1/7	1/4	1/4	1	2	2	1	3
T 5nm	1	1/2	1/2	1/2	1	4	7	7
T 7nm	1/4	1/2	1/2	1/2	1/4	1	6	6
T 14nm	1/5	1/3	1/4	1	1/7	1/6	1	1
T 16nm	1/7	1/4	1/5	1/3	1/7	1/6	1	1
TOTAL	3.40	6.33	7.70	18.33	8.54	15.33	28.00	34.00

0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.21
0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.21
0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.21
0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.21
0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07
0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07
0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07
0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07

Table 14

The power that manufacturing methods can give us is important to review, this may mean deciding significantly for another manufacturing method, but it is not the highest priority because choosing the most elaborate and modern process, may cost us more expensive.

Table 15 & 16

Criterio	S 5nm	S 7nm	S 8nm	S 14nm	T 5nm	T 7nm	T 14nm	T 16nm
S 5nm	1	1	1	1	3	3	3	3
S 7nm	1	1	1	1	3	3	3	3
S 8nm	1	1	1	1	3	3	3	3
S 14nm	1	1	1	1	3	3	3	3
T 5nm	1/3	1/3	1/3	1/3	1	1	1	1
T 7nm	1/3	1/3	1/3	1/3	1	1	1	1
T 14nm	1/3	1/3	1/3	1/3	1	1	1	1
T 16nm	1/3	1/3	1/3	1/3	1	1	1	1
TOTAL	5.33	5.33	5.33	5.33	16.00	16.00	16.00	16.00

0.29	0.47	0.39	0.38	0.12	0.26	0.18	0.21	0.29
0.10	0.16	0.26	0.22	0.23	0.13	0.11	0.12	0.17
0.10	0.08	0.13	0.22	0.23	0.13	0.14	0.15	0.15
0.04	0.04	0.03	0.05	0.23	0.13	0.04	0.09	0.08
0.29	0.08	0.06	0.03	0.12	0.26	0.25	0.21	0.16
0.07	0.08	0.06	0.03	0.03	0.07	0.21	0.18	0.09
0.06	0.05	0.03	0.05	0.02	0.01	0.04	0.03	0.04
0.04	0.04	0.03	0.02	0.02	0.01	0.04	0.03	0.03

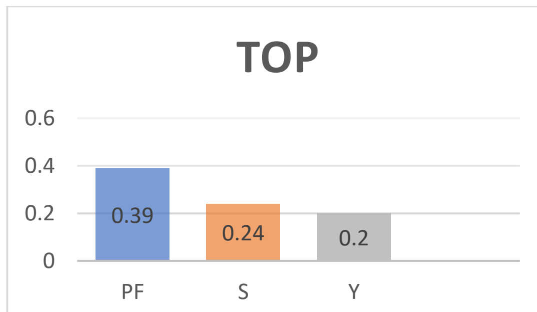
Finally, we will take all the weights of each criterion of each of the alternatives we have, place them in the matrix and add up each criterion to obtain which method is the best to select.

Criterio	PF	S	Y	Co	PT	TOP
S 5nm	0.21	0.27	0.29	0.35	0.29	0.28
S 7nm	0.21	0.15	0.19	0.15	0.17	0.17
S 8nm	0.21	0.15	0.13	0.13	0.15	0.15
S 14nm	0.21	0.12	0.12	0.09	0.08	0.12
T 5nm	0.07	0.14	0.11	0.15	0.16	0.13
T 7nm	0.07	0.10	0.09	0.05	0.09	0.08
T 14nm	0.07	0.04	0.04	0.05	0.04	0.05
T 16nm	0.07	0.02	0.03	0.03	0,03	0.03
W	0.39	0.24	0.20	0.12	0.06	

Table 17

In the following graph, the 3 criteria with a greater weight in the decision-making process are represented, a process that has more of these aspects can be the best, since it covers the most favorable aspects within the election.

Fig.3



All we have just done is the AHP process, at the beginning we have established a table from 1 to 7 to represent the priority or superiority of one model over the other, we saw our problem, we analyzed the characteristics of each of the manufacturing models and proceeded to choose the most relevant decision factors, in this case were: The country of origin, the stock, year of production, cost and the power that can represent each architecture.

Having already selected the decision factors one by one, we compared each decision factor according to its importance in each model. The way it works is to place the models and the decision factor to be analyzed in matrices. We use table 3 again and we mark a number from 1 to 7, being 1 the one that has less importance or is equal to the compared method, being 7 a representation of where the method is superior when compared with the others. And we wrote them in fraction in its counterpart of the compared method.

Once we made the tables with each decision factor we came up with the ones that have the most weight in the decision, the results are compelling, since things like year of production and stock directly affect the cost of production. Normally the country of origin would not have so much weight, but we are working in abnormal circumstances, since the global health situation changes the decision making game, so we must take into consideration how exports and industries work in the most affected countries, so it also affects the stock and the price of manufacturing methods. The year of manufacture is also important, since a very old method can make us very obsolete, but on the other hand a very new one can be very expensive to implement and sell.

Proporcionalidad.

The application of systematic proportionality has been applied in many areas, but if one area can be singled out, it would be the implementation of legal systems. In the vast majority of nations, the principle of proportionality has been born as the need to remedy the decisions taken by the legislature.[11]

Proportionality in the strict sense is made up of three elements: the law of proportionality, the law of the law of the law, and the law of the law of the law.

Proportionality in the strict sense is made up of three elements: the law of weighting, the formula of weight, and the burdens of argumentation. According to the law of weighting: The greater the degree of non satisfaction or restriction of one of the principles, the greater must be the degree of importance of the satisfaction of the other.) From the above it can be inferred that the law of weighting implies the development of three stages. In the first, the task is summarized in determining the degree of non-satisfaction or restriction of one of the principles. In the second, the importance of the satisfaction of the opposite principle is established. And in the third, "it must be defined whether the importance of the satisfaction of the opposing principle justifies the restriction or non-satisfaction of the other."[11]

The second step of the principle of proportionality in the strict sense is the weight formula. In general, two different versions can be established, depending on whether one prefers an arithmetical or geometrical view of the quantities. Those who prefer to work with arithmetic quantities develop the differential formula. "However, the differential formula does not account for a property that is central to the principles." If the values 2nd, 21st and 22 , i.e., 1, 2 and 4, are taken as a geometric series, it is shown as the difference of the arithmetic series, in this series, the "respective distances between the degrees are not equal but increase". Which represents "the fact that the principles gain increasing strength with increasing intensity of intervention, which is in harmony with the diminishing marginal rate of substitution" [11].

Equation 5

$$GPi,jC = \frac{IPic.GPiA.SPiC}{IPic.GPiA.SPiC}$$

IRR.

he internal rate of return (IRR) is the interest rate or profitability offered by an investment. That is, it is the percentage of profit or loss that an investment will have for the amounts that have not been withdrawn from the project.[12]

It is a measure used in the evaluation of investment projects that is closely related to the net present value (NPV). It is a measure used in the evaluation of investment projects that is closely related to the net present value (NPV). It is also defined as the value of the discount rate that makes NPV equal to zero, for a given investment project.[12]

It is a measure used in the evaluation of investment projects that is closely related to the net present value (NPV). The internal rate of return (IRR) gives us a relative measure of profitability, i.e., it will be expressed as a percentage. The main problem lies in its calculation, since the number of periods will give the order of the equation to be solved.[12]

MOORA

The methods of decision making with multiple criteria (MCDM), generate as a result an index or ranking of the best answers found

The MOORA method, first introduced by Brauers (2004) is a multiobjective optimization technique that can be successfully applied to solve various types of complex decision-making problems in a manufacturing environment

Step 1: Create a Decision Matrix.

The decision matrix is represented as the Xij matrix, where i is, m that is the number of alternatives whereas j represents n in the number of criteria, equation 1 is the matrix representation of the decision.

Equation 6

$$x = \begin{bmatrix} x_{11} & x_{12} & . & x_{1n} \\ x_{21} & x_{22} & . & x_{2n} \\ . & . & . & . \\ x_{m1} & x_{m2} & . & x_{mn} \end{bmatrix}$$

Step 2: Normalize the Decision Matrix

Brauers (2008) concludes that for this denominator, the best option is the square root of the sum of squares of each alternative per attribute. This ratio can be expressed as follows:

$$x_{ij}^{*} = x_{ij} / \sqrt{\left[\sum_{i=1}^{m} x_{ij}^{2}\right] \; (j = 1,2,\dots,n)}$$

Equation 7

Step 3: Optimize attributes.

For multi-objective optimization, these normalized performances are added in case of maximization (for favorable attributes) and reduced in case of minimization (for non-beneficial attributes). Then the optimization problem becomes:

Equation 8

$$y_i = \sum_{j=1}^{g} x_{ij}^{*} - \sum_{j=g+1}^{n} x_{ij}^{*}$$

When the weight of this attribute is considered, Eq. 3 being as follows:

Equation 9

$$y_i = \sum_{j=1}^{g} w_j x_{ij}^{*} - \sum_{j=g+1}^{n} w_j x_{ij}^{*} \; (j = 1,2,\dots,n)$$

Aplication

Table 18

Alternativa	Pais de origen	Anio	Potencia	stock	costo
s 5nm	1	2021	2800	0.25	17000
s 7nm	1	2019	1442	0.5	9000
s 8nm	1	2018	1104	0.5	6800
s 14nm	1	2016	360	0.5	5500
t5nm	0.5	2020	2827	0.25	16988
t 7nm	0.5	2019	1442	0.25	9436
t 14nm	0.5	2017	360	0.5	5500
t 16 nm	0.5	2015	276	0.5	3974
PESO	0.39	0.2	0.06	0.29	0.12

Table 19 criteria multiplied squared

Alternativa					
s 5nm	1	4084441	7840000	0.0625	289000000
s 7nm	1	4076361	2079364	0.25	81000000
s 8nm	1	4072324	1218816	0.25	46240000
s 14nm	1	4064256	129600	0.25	30250000
t5nm	0.25	4080400	7991929	0.0625	288592144
t 7nm	0.25	4076361	2079364	0.0625	89038096
t 14nm	0.25	4068289	129600	0.25	30250000
t 16 nm	0.25	4060225	76176	0.25	15792676
SUMATORIA Y RAIZ	2.236067977	5708.12202	4641.64292	1.198957881	29498.52396

*Table 20. xij**

s 5nm	0.447213595	0.354056902	0.603234684	0.208514414	0.576300022
s 7nm	0.447213595	0.353706524	0.310665862	0.417028828	0.305100011
s 8nm	0.447213595	0.353531335	0.237846818	0.417028828	0.230520009
s 14nm	0.447213595	0.353180957	0.077558745	0.417028828	0.186450007
t5nm	0.223606798	0.353881713	0.60905159	0.208514414	0.575893222
t 7nm	0.223606798	0.353706524	0.310665862	0.208514414	0.319880412
t 14nm	0.223606798	0.353356146	0.077558745	0.417028828	0.186450007
t 16 nm	0.223606798	0.353005768	0.059461705	0.417028828	0.134718605

*Table 21. XIJ*W*

s 5nm	0.174413302	0.07081138	0.036194081	0.06046918	0.069156003
s 7nm	0.174413302	0.070741305	0.018639952	0.12093836	0.036612001
s 8nm	0.174413302	0.070706267	0.014270809	0.12093836	0.027662401
s 14nm	0.174413302	0.070636191	0.004653525	0.12093836	0.022374001
t5nm	0.087206651	0.070776343	0.036543095	0.06046918	0.069107187
t 7nm	0.087206651	0.070741305	0.018639952	0.06046918	0.038385649
t 14nm	0.087206651	0.070671229	0.004653525	0.12093836	0.022374001
t 16 nm	0.087206651	0.070601154	0.003567702	0.12093836	0.016166233

Table 22 Results & TOP

YI		TOP
s 5nm	0.272731941	**4**
s 7nm	0.348120918	**3**
s 8nm	0.352666338	**1**
s 14nm	0.348267378	**2**
t5nm	0.185888083	**8**
t 7nm	0.198671438	**7**
t 14nm	0.261095764	**6**
t 16 nm	0.266147635	**5**

Results.

Moora was a better procedure for the realization of this project, because of 2 main things: The ease of MOORA and the weight of the negative aspects that MOORA gives to the problem.

Thanks to the way MOORA treats the aspects, it gave us a table with more satisfactory results and with more sense than with AHP, it is not AHP's fault, it is really that the way in which the aspects of the alternatives are evaluated is not as good as AHP, since AHP needs the direct comparison, things like the year cannot be compared as easy in AHP as Moora does.

However, I find the way to get the weights in AHP very satisfactory and that is why I used the same weights in MOORA that had already been calculated previously with AHP.

Using the matrix operations that the Moora method incorporates we were able to determine, which of the manufacturing methods available to use would be optimal. In the top, we can see how in the realization of the Moora method, a special case happened, that in other circumstances will not occur, which is, all TSMC methods lost, this was because of the global health situation, being TSMC a Chinese company, today it is difficult to get stock of it, so the score of each of the methods suffered to find the advantage that Samsung has to be in South Korea. An interface has been created in JavaScript for decision making with the selected methods.

Imagen 1. Interface of registración.

Image 2. Table

MODULO DE PROGRAMACION

NOM 035 PREZI Y PAPER METODO MOORA DA CLCIK AQUI

TABLA GRAFICA modulo x MODULO X

Fabricante	Metodo de Fabricacion	Densidad de transitores	Anio	Costo estandar de produccion por oblea	Litografia	Pais de Origen	Tamnio de oblea	Cantidad de chips por oblea	Cantidad estimada de chips con un defecto	Cantidad estimada de chips inservibles	Disponiblidad de stock
TSMC	5mm	127	2020	17000dlls	DUV	China	300mm	2827	1%	0%	Muy bajo
Samsung	5mm	120	2020	17000dlls	DUV	Corea del Sur	300mm	2827	1%	0%	Muy bajo
TSMC	7mm	95	2019	9000dlls	EUV	China	300mm	1442	3%	0%	Bajo
Samsung	7mm	63	2019	9436dlls	EUV	Corea del Sur	300mm	1442	3%	0%	Bajo
Samsung	8mm	61	2018	6800dlls	EUV	Corea del Sur	300mm	1104	4%	0%	Bajo
Samsung	14mm	32	2017	5500dlls	183mm	Corea del Sur	300mm	360	13%	1%	Medio
Samsung	16mm	29	2015	3984dlls	183mm	Corea del Sur	300mm	276	18%	1%	Medio

For each manufacturing process we have calculated its costs according to its manufacturing process and the probabilistic variables of how much waste it would have.

Image 3. TIR

PROGRAMMING MODULE

NOM 035 PREZI & PAPER MOORA METHOD

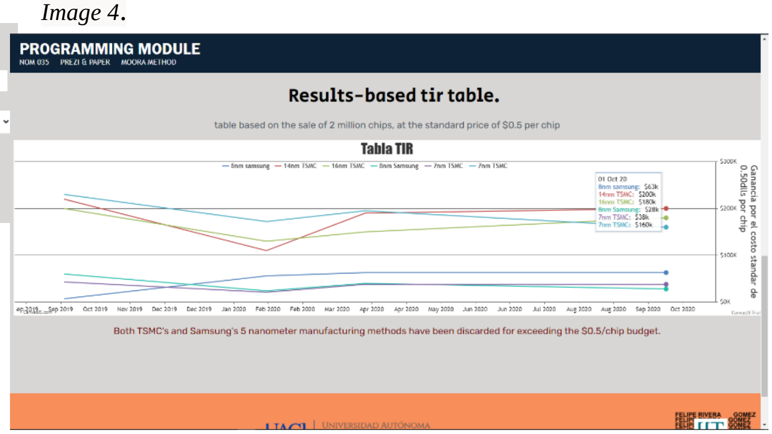
The following table shows the capital investment required for the production of 2,000,000 chips. The data does not take i blades.

method	Investment required	Development cost per chip.	Losses due to dead chips.	Stock
5mm	1401792	1.426745194722184	24789.067142008316	25,000 dlls extras por oblea
5mm	1428000	1.4005602240896358	25252.52525252525	25,000 dlls extras por oblea
7mm	756000	2.6455026455026456	26203.20855614973	10,000 dlls extra por oblea
7mm	792624	2.5232644986778094	27472.608437314317	25,000 dlls extras por oblea
8mm	571200	3.5014005602240896	25858.58585858586	10,000 dlls extra por oblea
14mm	503328	3.973552037637485	69782.05585264409	solo se agregan cotos de envio
14mm	462000	4.329004329004329	64052.28758169934	solo se agregan cotos de envio
16mm	334656	5.976286096768025	60600.35650623886	solo se agregan cotos de envio

Results-based tir table.

And with this, an IRR graph has been elaborated, and the 5nm methods have been eliminated because of their high costs.

Image 4.



After this, a transcription has been made providing the advantages of each manufacturing method.

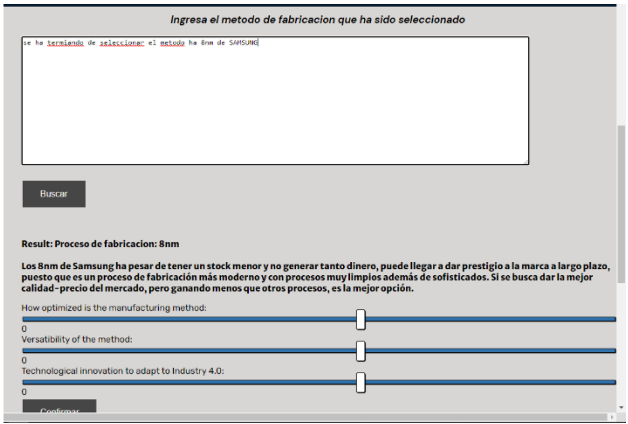
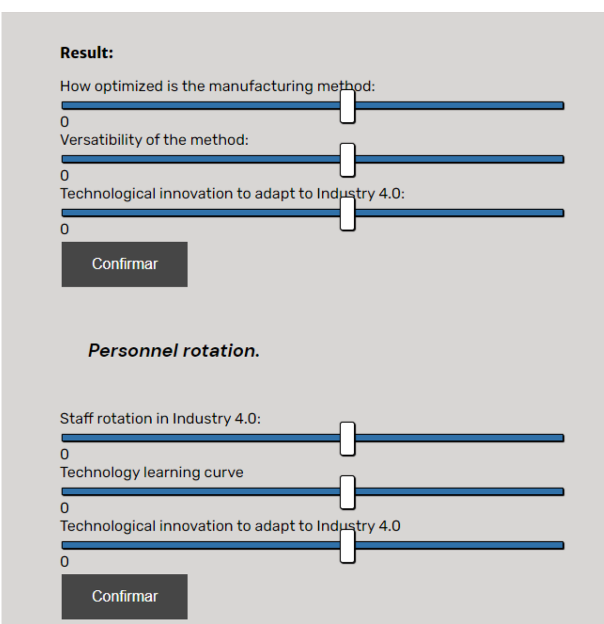


imagen 5

In addition, data from the technology learning pipeline, such as technology implementations, has been provided.



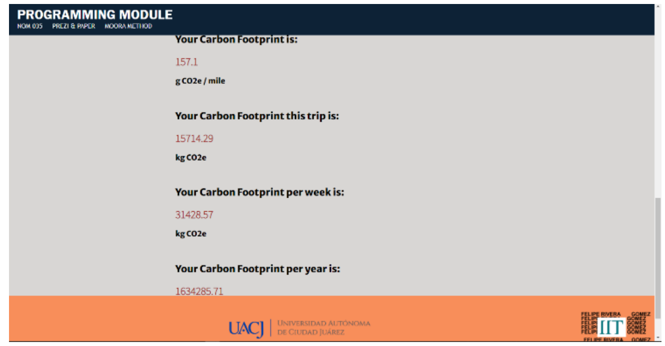


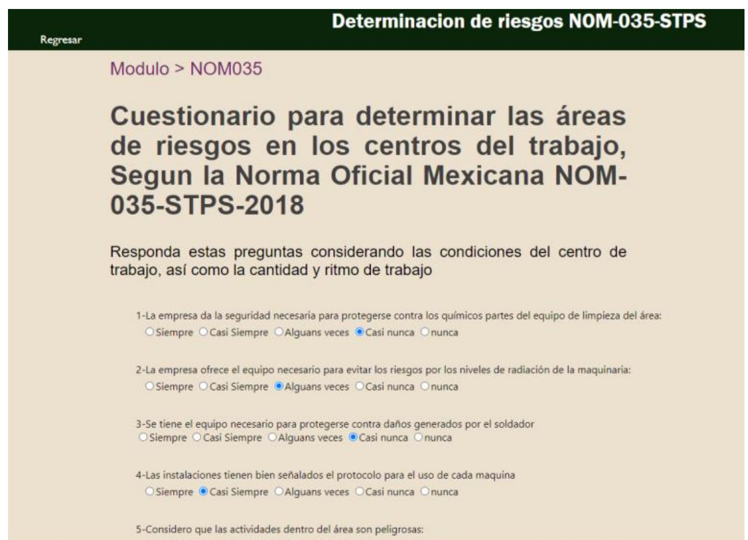
Imagen 6

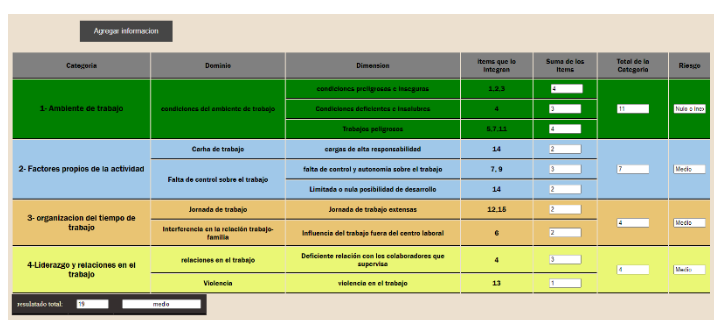
Information has been provided to calculate the carbon footprint of silicon wafer transportation as an impact on the environment.

Image 7

After this, the risks of the work area were determined using NOM-035 and recorded in a table.

Image.8, 9 & 10





Agregar informacion

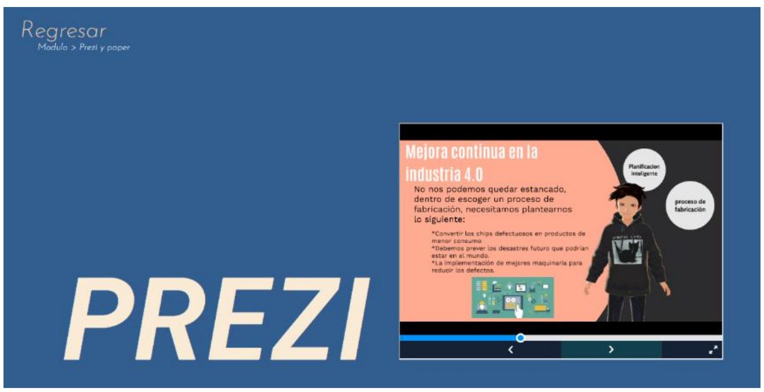
Categoria	Dominio	Dimension	Items que lo integran	Suma de los Items	Total de la Categoria	Riesgo
1- Ambiente de trabajo	condiciones del ambiente de trabajo	condiciones peligrosas e inseguras	1,2,3	4	11	Nulo o ines
		Condiciones deficientes e insalubres	4	3		
		Trabajos peligrosos	5,7,11	4		
2- Factores propios de la actividad	Carha de trabajo	cargas de alta responsabilidad	14	2	7	Medio
	Falta de control sobre el trabajo	falta de control y autonomia sobre el trabajo	7, 9	3		
		Limitada o nula posibilidad de desarrollo	14	2		
3- organizacion del tiempo de trabajo	Jornada de trabajo	Jornada de trabajo extensas	12,15	2	4	Medio
	Interferencia en la relación trabajo-familia	Influencia del trabajo fuera del centro laboral	6	2		
4-Liderazgo y relaciones en el trabajo	relaciones en el trabajo	Deficiente relación con los colaboradores que supervisa	4	3	4	Medio
	Violencia	violencia en el trabajo	13	1		

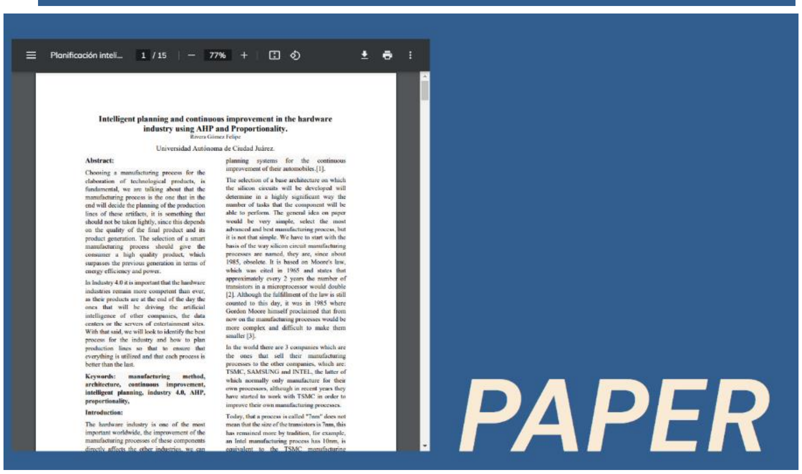
resulatado total: 19 medio

Nombre del trabajador	Edad	Puesto de Trabajo	Puntaje de la NOM035	Nivel de riesgo
Felipe Rivera	19	calidad	19	Medio
Valdimir Hamabata	20	calidad	17	Medio
Daniel Mora	23	Produccion	23	Alto
Abrham Herrera	19	Fan de Kanye West	10	Bajo

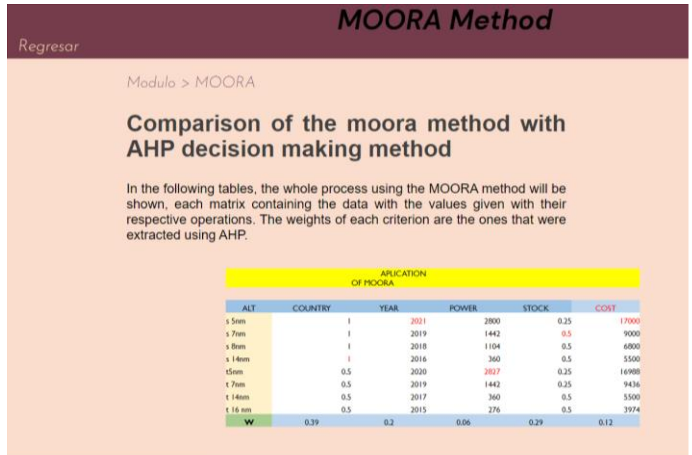
In this graphical interface, a Prezi presentation has been provided presenting the project and the paper being read..

Image 11 & 12





Finally, the moora method has been introduced within the interface.



ALT	COUNTRY	YEAR	POWER	STOCK	COST
s 5nm	1	2021	2800	0.25	17000
s 7nm	1	2019	1442	0.5	9000
s 8nm	1	2018	1104	0.5	6800
s 14nm	1	2016	360	0.5	5500
t5nm	0.5	2020	2827	0.25	16988
t 7nm	0.5	2019	1442	0.25	9436
t 14nm	0.5	2017	360	0.5	5500
t 16 nm	0.5	2015	276	0.5	3974
W	0.39	0.2	0.06	0.29	0.12

Image 13

CONCLUTION

The results presented with MOORA have been more satisfactory for my project, with this work I have seen how great moora is a very simple and very effective method, unlike AHP, I have noticed that MOORA can adapt better in special circumstances as in the current pandemic, thanks to the way it works, MOORA is a great method and one very easy to learn.

The limitations of AHP have taken their toll on the results, as it has undermined methods that with AHP fared better. It is important to learn MOORA because as I have noticed in this work, I can see the superiority of this method in decision making over others.

Translated with www.DeepL.com/Translator (free version)

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