**Journal of Theoretical and Applied Information Technology**
30th September 2022. Vol.100. No 18


ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

# IMPROVE MANUFACTURING QUALITY CONTROL WITH ARTIFITIAL INTELLIGENCE

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**ABSTRACT**

Stagnation has no place in the modern industrial world, especially when it comes to quality. To remain successful in a competitive environment, any company must improve on all levels, including quality, which is a key index to measure its performance. The sources of waste, failure and non-quality are the real obstacles to production and its quality, so it is necessary to identify and remedy them. Improving production quality (quality approach) requires a particular attention to processes and operational organization, in particular by redefining technical support (thanks to new technologies) and by implementing adapted quality tools.

The control at the end of the production line is essential to ensure the manufacturing quality of each product. Quality control can be fully automated but human verification is also very often undertaken by qualified operators.

Rising production and raw material costs are creating a growing need for automated quality control throughout the production chain. It is an essential tool to reduce manufacturing errors and therefore waste at the end of the chain.

The research work presented in this article aims to establish a model allowing the company to enter the industry 4.0 (or industry of the future) through the automation of quality control to improve their reliability by freeing themselves from human errors related to the repetitive nature of these tasks. to measure the quality index of production within the industrial chains. Indeed, the conformity of products cannot yet be guaranteed directly without measurement. This last one (conformity measurement) allows to locate and follow the evolution of a parameter in time, to analyze it on a given period, to correlate it with other related values and to act to improve it in order to control and adjust the production process in real time; This decision support model is based on the fuzzy logic theory, it consists in modeling the relevant decision criteria which influence the quality of the production, which are: the rate of conformity, the rate of reworked product and the rate of non-conforming product but accepted under exemption. Thus, determine the most predominant factor.

For the validation of this proposed model, an experimental study was conducted to control the production quality in an automotive parts manufacturing line. The proposed model meets the desired objective and is therefore retained as a model to ensure the quality of a manufactured product.

***Keywords :*** *Quality Control, Artificial Intelligence, Product Line, Industry 4.0* **,**

## 1. INTRODUCTION

Quality is an important part of the horizontal monitoring of production, from the receipt of raw materials to the delivery of products, quality control must be carried out systematically (INLINE) or by sampling (OFFLINE). Quality control is a procedure (or a series of procedures) to ensure the quality of a manufactured product [1]. In this respect, the products must meet a defined set of quality standards and the most important customer requirements.

The following figure is an example of a delocalized indirect quality.

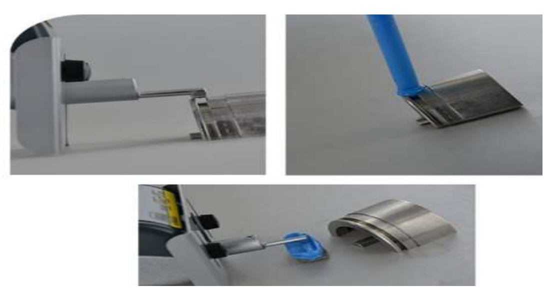

*Figure 1. External control of quality example.*

In terms of performance, product losses due to non-quality obviously play a crucial role. The quality

Journal of Theoretical and Applied Information Technology
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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

rate is one of the three components of the OEE (Overall Equipment Effectiveness) which measures the productivity of a line or a production unit [2].

"The optimal quality level must not produce inadequate costs (over-quality)" [3]. Quality, like any other activity in a company, has a cost, but this is supposed to reduce the cost of non-quality.

The proposed method focuses on different aspects of a company's operations in order to improve its production. This includes everything from managing the business to identifying the cause of failure, solving and preventing problems, and verifying the reliability of the process. "These are all factors that can have a direct or indirect impact on production quality" [4]. Fuzzy logic is presented as a connected and controlled tool that allows companies to implement the necessary corrections.

First, we describe the approach and define the major criteria related to production quality. Then, we present the modeling of these factors [5] by the membership functions. Then, we develop the decision rules and at the end, we analyze the results.

## 2. LITERATURE REVIEW

In order to rule on the industrial performance in terms of quality in a manufacturing line, several studies have been conducted with different strategies to improve quality. One of the most followed methods is Overall Equipment Effectiveness (OEE), which is a Lean tool of the most commonly used measures in operations (Andersson & Bell, 2014). OEE is a "best practice" measure that identifies the percentage of planned production time that is actually productive. An OEE score of 100% represents perfect production: making only good parts, as quickly as possible, with no downtime (Saha, Syamsunder & Chakraborty, 2016) [A]. Garza-Reyes (2015) introduced a new metric "overall resource efficiency (ORE)," which focuses on performance factors such as efficient use of raw materials and materials [6]. According to Garza-Reyes et al. (2010), OEE can be used as an indicator of process improvement.

In 1995, the American company General Electric and its CEO Jack Welch developed their version of the quality management system called Six Sigma. Six Sigma is based on statistical measurement and data analysis [6]. The three main target areas in Six Sigma are: - Defect reduction - Cycle time reduction - Customer satisfaction improvement. Six Sigma starts first and foremost with the customer. The idea is to use statistical measures to analyze the process or the product (Holpp and Pande, 2002, p.7) [6].

While OEE, Six Sigma and Lean are the dominant quality management systems, the technological growth will evaluate and require the integration of new technology split on artificial intelligence like fuzzy logic to keep up with the unpredictable change in the industrial market hence the objective of our proposed model in this article.

In our research work proposes a model to measure the industrial quality in the production line in real time through a selection of criteria impacting the quality and establish fuzzy rules through the technology of fuzzy logic. The simulation of the results is obtained through the software matlab. This model allowed the experts to determine the most impactful and powerful criteria to adjust and increase the industrial quality in the production lines.

## 3. METHODOLOGY

### 3.1. Processus De La Logique Floue (FL)

Fuzzy logic is a method used in artificial intelligence based on "the value or degree of truth" in the form of real numbers between 0 and 1. In this, it differs from classical Boolean logic based on two values "true or false" (1 or 0). In other words, this so-called universal logic admits the possibility of partial truths, located at the two extremes of 0 and 1. Fuzzy logic was formulated by the mathematician Lotfi Zadeh in the 1960s as part of his research on the understanding of language by computers.

Natural language is difficult to translate into absolute and binary terms (like 0 or 1) and cannot be described by strict Boolean logic. To overcome this, it is necessary to develop a logic that is closer to the way the human brain works, which tends to combine partial facts to make acceptable decisions. Fuzzy logic does this by more accurately representing human cognitive abilities. In this respect, it is essential for the design and development of AI capabilities when faced with complex and/or unusual tasks.

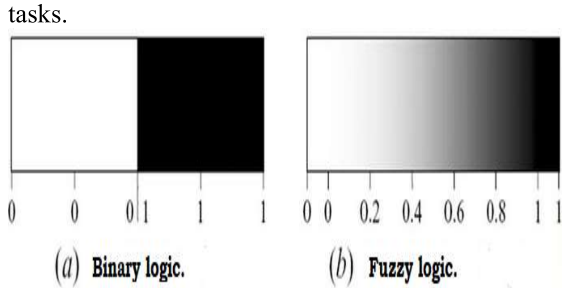


*Figure 2. Range of logical values in Binary and Fuzzy logic.*

Figure 2 illustrates the difference between fuzzy logic and binary logic.

The Value 0 corresponds to the white color, since the color approaches the black as the numerical value tends towards 1.

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2.2/ Proposed model description

For our model, an approach based on the process of fuzzy logic was adopted, this approach is divided into five main steps

- The definition of linguistic variables;
- The fuzzy presentation of the variables;
- The establishment of fuzzy inference rules;
- Defuzzification.

An extensive description of each step will be provided below.

STEP 1: Definition of linguistic variables**:**

"Compliance is confirmed when a product passes all quality tests" [7]. The product is compliant and can proceed to the next step (Assembly, Marketing, etc.) When a product is not compliant, one (or more!) is required to pass the audit. Does not meet the requirements. It is most often a matter of detecting the root cause and then examining the non-conformities: the product will be modifiable, accepted with a waiver or scrapped.

The descriptive flowchart of the proposed quality control is schematized in the figure 3

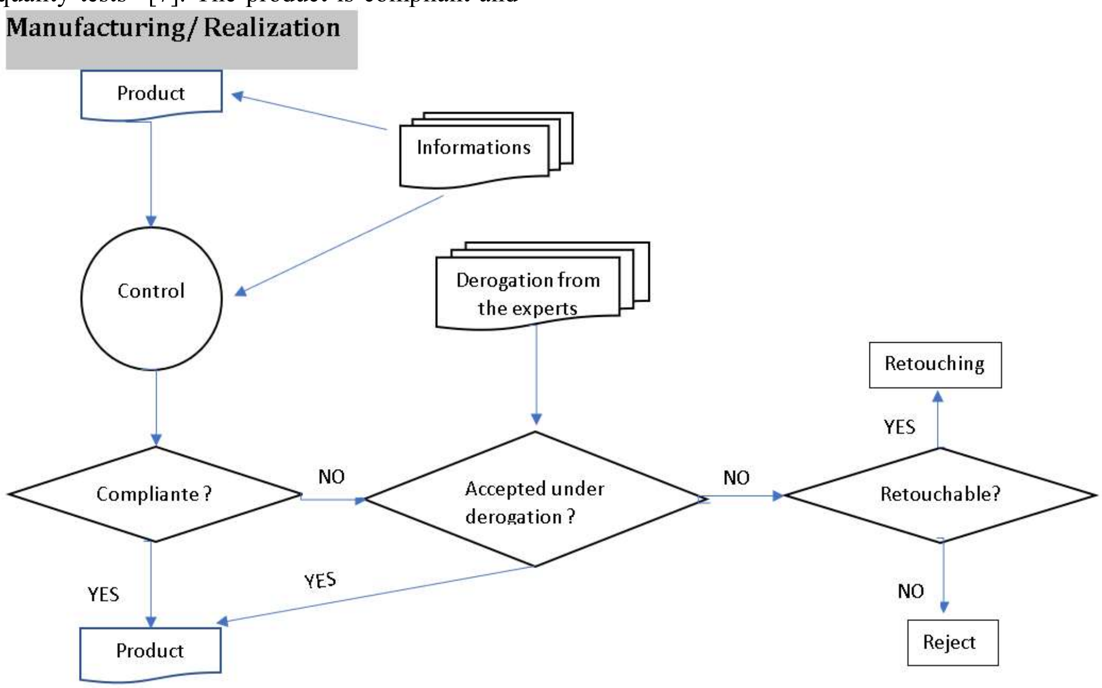


*Figure 3. Quality Control Process Flowchart.*

**3.4. Defuzzification**

Graphically, the following figure shows the defuzzification step, which consists in transforming the fuzzy set associated with the inputs: Cost, Quality and Delay into a net value by applying the center of gravity method.

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So, the variables of our model are: the rate of compliance; the rate of reworked products and the rate of products accepted by the experts.

STEP 2: The fuzzy presentation of variables.

Once the input variables have been identified, a "fuzzification" phase is initiated, which aims at converting the numerical data into linguistic variables. To do this, fuzzy system designers must create membership functions [8]. “A membership function is a function that defines the degree of membership” [9]. The membership function is normalized between 0 and 1 (the ordinate axis) and the domain of discourse (the abscissa axis) by defining a function for each variable and a subset (class) for a function.

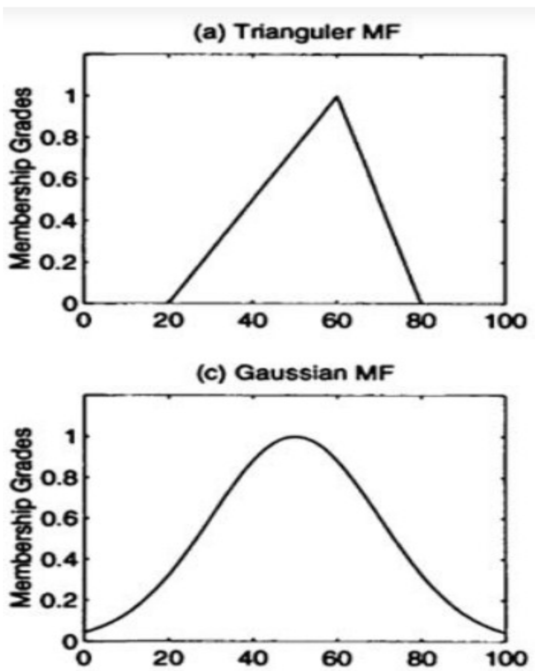


*Figure 4. Some types of Fuzzy membership functions.*

As shown in Figure 4. The membership functions can take any form you want, as long as that form makes sense for the variable you are trying to explain.

STEP 3: The establishment of fuzzy inference rules

This step consists of defining the decision rules <If..., Then> set by the experts to the input variables using the fuzzy operators <<OR>> or <<AND>>.

"The fuzzy engine is in charge of applying each of the inference rules. These inference rules represent the knowledge that we have of the system due to human expertise. Each rule will generate an output command.

STEP 4: Defuzzification

"This is the step that merges the different commands generated by the inference engine into a single output command and transforms this output linguistic variable into numerical data.

The procedure on which the fuzzy values are minimized into numerical values by using different methods like Max-Min, Centroid...

The fuzzy inference system schematized in this figure consists of three parts.

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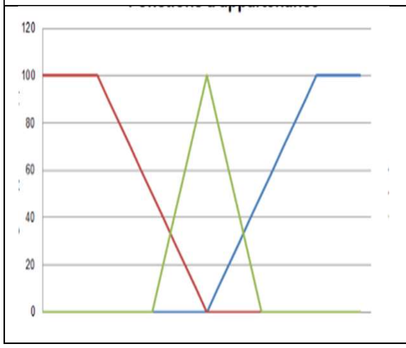
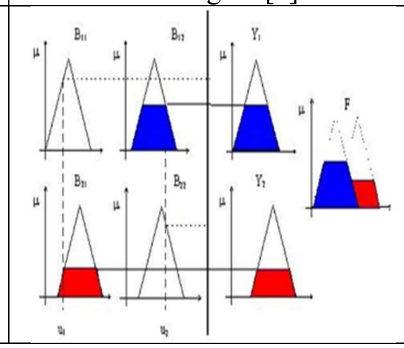
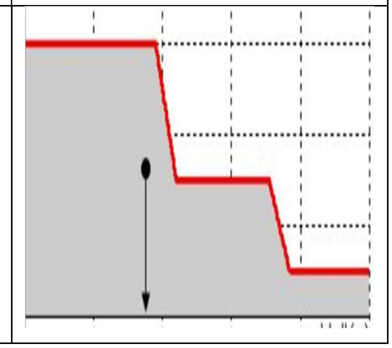
| Fuzzification. | Inference engine [1]. | Deffuzification. |
| --- | --- | --- |
|  |  |  |

*Table 1. Processus of fuzzification [6].*

## 4. CASE OF STUDY.

### 3.1. Indicators Definition

Conformity: is the fact that the product meets the measurements and requirements of the conformity standards established during production.

So, Compliance rate $=\frac{number\ of\ conforming\ pieces}{number\ of\ pieces\ produced}$

Retouch: Action applied to a non-conforming product to make it acceptable for its intended use [9].

So, the Retouch rate $=\frac{number\ of\ pieces\ to\ be\ retouched}{number\ of\ pieces\ produced}$

Reject: Action taken on a non-conforming product to prevent its use as originally intended [10].

So, Reject rate $=\frac{number\ of\ discarded\ parts}{number\ of\ produced\ parts}$

Derogation (After production): Permission to use or make available a product that meets requirements [11].

Under-derogation rate $=\frac{number\ of\ non-comformed\ pieces\ but\ accepted\ under\ derogation}{number\ of\ pieces\ produced}$

Thus, our model will be schematized as follows

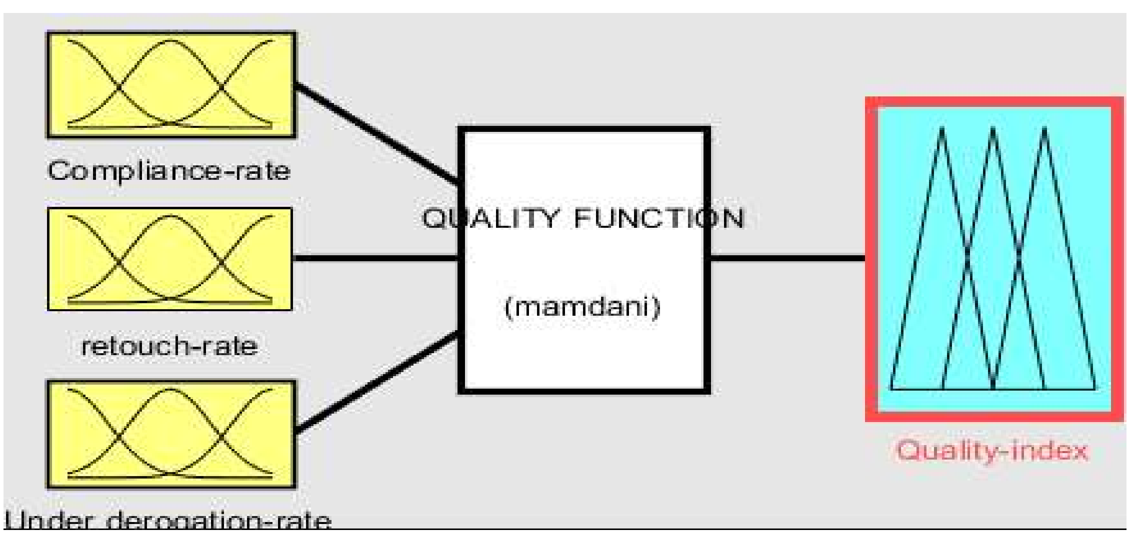



*Figure 5. The Fuzzy model.*

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### 3.2. Modeling of Indicators

The figure below shows the membership function compliance rate μ (compliance rate) to a universe of discourse with subsets <L: Low, H: High> using Mamdani as an inference type [12].

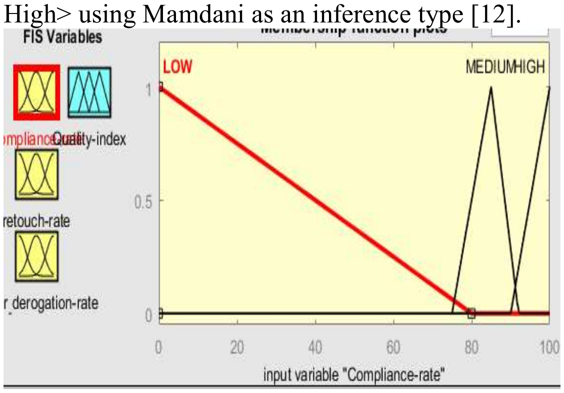


*Figure-6. Membership Function For "Compliance Rate".*

The other indicators are modeled by the same principle by membership functions of different type using linguistic terms appropriate to each indicator.

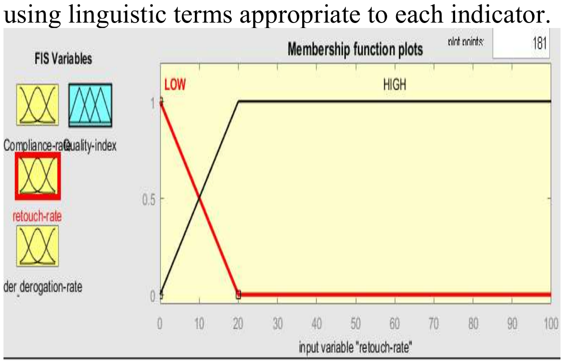


*Figure 7. Membership Function For "Retouch Rate"*

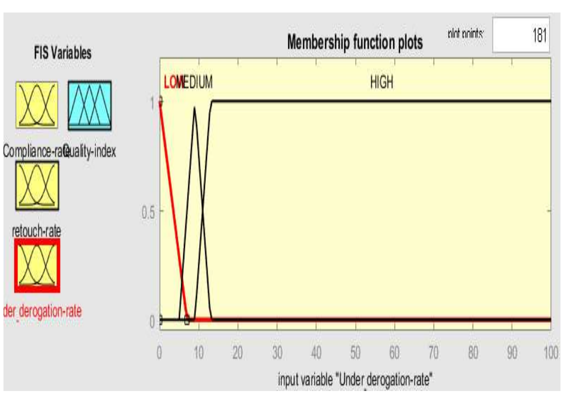


*Figure 8. Membership Function For "Under-Derogation Rate.*

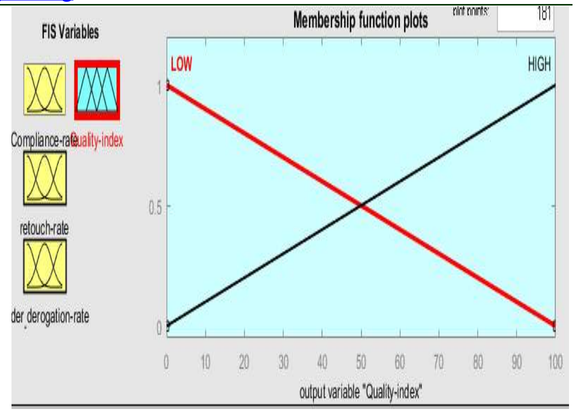


*Figure 9. Membership Function For The System Output "Quality Index".*

3.3/ Fuzzy Inference

The part where the experts define the fuzzy rules using the set of input indicators [13]. In our case study we set up 12 fuzzy rules (3*2*2) with the <<ET>> operator.

### 3.4. Defuzzification

Graphically, the following figure shows the defuzzification step, which consists in transforming the fuzzy set associated with the inputs: Cost, Quality and Delay into a net value by applying the center of gravity method.

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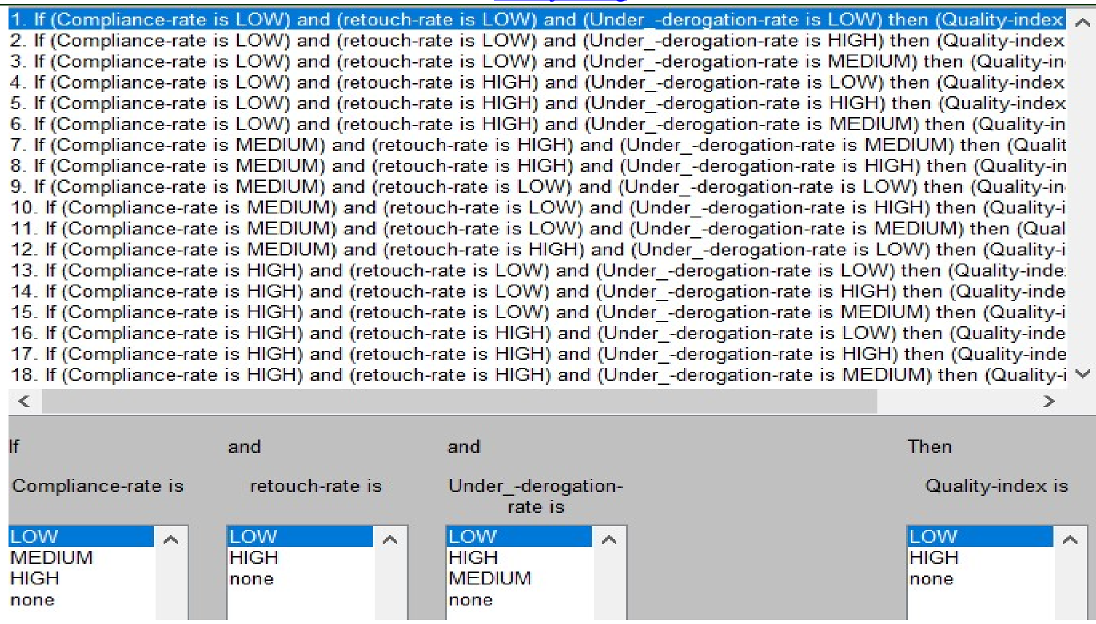


*Figure 10. Rules editor.*


*Figure-11: Visualization of decision rules*

## 4. RESULTS AND DISCUSSION

The surface represents the three-dimensional relationship between the various inputs and outputs. Relationships depend on the rules made [14]. The very random fluctuations on the surface represent weaknesses and at the same time indicate the wrong development of the established rules.

To analyze the surfaces, we work with only 2 inputs and we fix the third one on a constant value (abscissa axis) and we visualize the result of the output on the coordinate axis.

Case N°1: (Med, Y, Z)

Dans ce cas l'indicateur du taux de sous dérogation est fixé en moyen.

Medium: Compliance rate.

Y: Retouch rate.

Z : Under-derogation rate.

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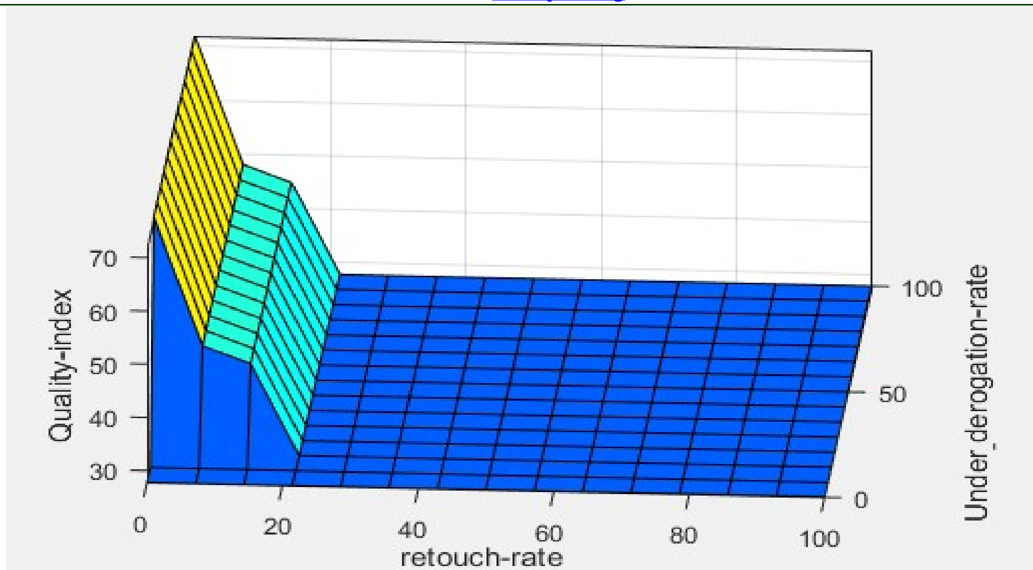


*Figure 12 : le cube pour le cas N°1 : (Med, Y, Z)*

The interpretation of Figure 11 shows the close relationship between Quality index and three arameters: Compliance rate, Retouch rate and Under-derogation rate.

For example, with a medium Compliance rate value, i.e. 0.5, it is clear that Quality index is high when Retouch rate is Low and Under-derogation rate is Medium or High.

However, it's Low when Retouch rate and Under-derogation rate are Low or when Retouch rate is Medium or high regardless of the value of Under-derogation rate.

<u>Casee N°2: (X, Med, Z).</u>

Dans ce cas l'indicateur du taux de conformité est fixé en moyen.

X: Compliance rate.

Medium: Retouch rate.

Z : Under-derogation rate.

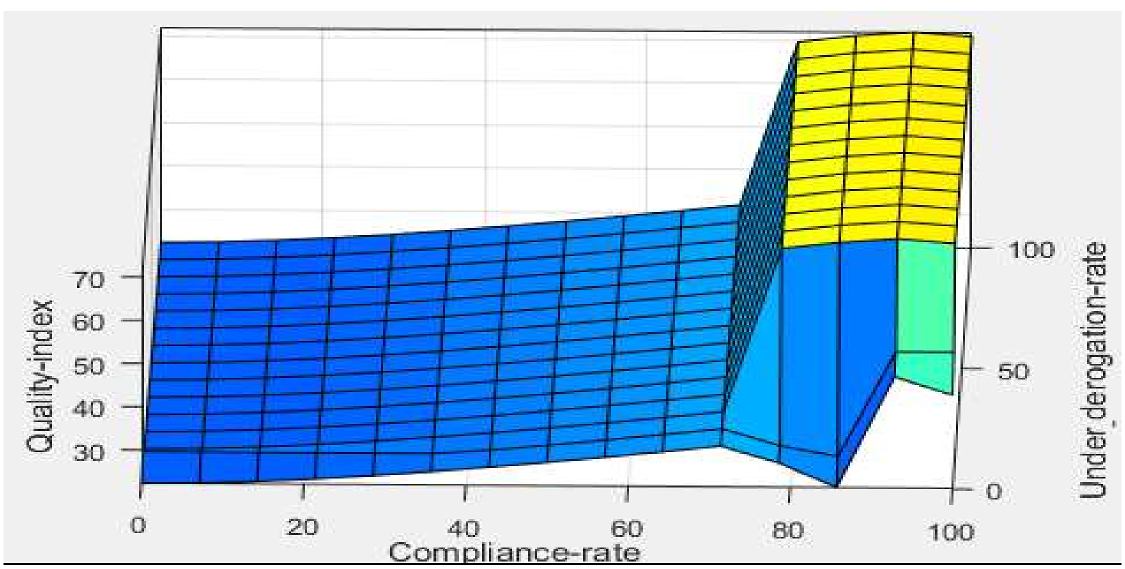


*Figure 13 : le cube pour le Cas N°2 : (X, Med, Z).*

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The surface showing demonstrates that Quality index is High when Compliance rate is High and Under-derogation rate is Medium or High.
It is Low when Compliance rate is Low or Medium regardless of the value of Under-derogation rate, also, when Compliance rate and Under-derogation rate are High.
The results obtained are not found in binary logic where the supplier score will be null if only one of the input parameters is null, hence the advantage of fuzzy logic
This simulation is a direct projection to the decision rules set up by the experts, hence the usefulness of modifying these rules if necessary via rule recovery and the allocation of appropriate membership functions to each input variable.
This result depends essentially on the weighting of the input criteria. Reflected by the decision rules [15]. The result obtained is associated to each company, since it is the company that defines in advance the weighting of the input criteria and the one among them that matters the most.

## 5. CONCLUSION.

Ensuring product quality has become critical for companies, not only to meet customer requirements, but also sometimes for legal reasons. Therefore, a quality control process must be in place within the company. Whether it is an internal consideration to provide a quality product, or a legal or contractual obligation, quality control is a reality you must face. There are two types of quality control, acceptance control and production control [16]. In both cases, the goal is to detect anomalies in the product. There are different ways to perform quality control. You can start with a 100% inspection, testing every part in the lot, or you can choose a sample inspection to select only some of the parts in the lot.
In either case, it's important to detect and address nonconformances effectively so that the company's profitability is not affected. Failure to quickly identify the source of the problem, or worse, the problem itself, can result in production line stoppages or the production of unrecoverable parts, which is problematic.
In this paper, we demonstrate the feasibility of building an artificial intelligence model based on fuzzy logic theory that allows companies to control and maintain a quality management system. As a result, the performance of the entire enterprise is improved. The integration of AI via fuzzy logic is an innovative NDT solution that enables fast and highly efficient dimensional or surface condition inspections. It is a solution that takes only minutes and its footprint remains.
Although it is a decision support tool for monitoring quality indicators in real time, the proposed models based on fuzzy logic theory require a thorough study of quality parameters by domain experts before companies can establish relationships between them. The results obtained vary considerably with changes in these fuzzy relationships that reflect the weights of different decision parameters, so the model is very challenging. The ingenuity of the model is that companies can model and adapt the decision criteria to their needs by weighting them, which is a direct prediction of the decision rules. From then on, the company will develop its own unique model based on influential criteria.
Our main objective is to exploit the knowledge of experts to establish decision rules and artificial intelligence to use them and establish a model based on fuzzy logic to ensure the monitoring of management system to anticipate and proceed to preventive and corrective actions for a continuous improvement of the company's performance.

## 6. LIMITATIONS

Our proposed research work must be based on a large quantity of data to allow experts to have a vision on the criteria and parameters impacting the quality and to select among them the most important ones. This makes it an expensive technology to apply.
The results obtained are very sensitive to the fuzzy rules established by the experts, so a poorly established rule or a poorly chosen criterion by the experts makes the proposed fuzzy logic model vulnerable.
Moreover, the absence of tools to measure the performance and evaluate the quality of our study model. Thus, the imprecision and distorted values given by the model seriously impact the quality system.

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