

# Defining quality and maturity level applying the grey system and the method for automotive enterprises diagnosis

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**Abstract:** This study intends to diagnose the maturity level of companies certified by the Automotive Quality Management System ISO TS 16949: 2009. Thus, it analyzes if those are considered World Class Organizations (WCO), identifying its management strengths and weaknesses, to provide input for improvement opportunities in their systems. This study methodology applies the Questionnaire Benchmarking Industrial from the Institute Euvaldo Lodi of Santa Catarina (IEL / SC) using the Method for Enterprises Diagnosis (MED). Therefore, it was performed using quantitative analysis regarding the degree of companies' maturity, applying the Grey Correlation Analysis System. Considering this research limitations and implications classify, its results are classified as exploratory. Future research may focus and study the correlation between a greater number of companies certified by ISO TS. Broad-based and larger sample size would provide a better picture for ISO TS and each organizations maturity state. This study value lies in the ability of diagnosing the organization maturity level, applying MED, Industrial Benchmarking and Grey System tools. Those allowed to define weaknesses and strengths of each organization in analysis. The study resulted in the identification of a systematic way to guide new projects and initiatives, to support and develop strategic planning and to identify how organizations are establishing world class standards.

**Keywords:** ISO TS 16949, Automotive, World Class Benchmarking, Grey Method

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## 1. Introduction

The ISO TS 16949 is a technical specification for a quality management system to achieve world class levels of product quality, productivity, competitiveness and continuous improvement in the global automotive industry [1,2]. An ISO TS represents an agreement between members of a technical committee, which has been voted and accepted for publication once approved by 2/3 of its quorum (ISO TS 16949, 2009). Johnson et al. [3] says that if we cannot measure, we cannot improve. For this management system, the ISO TS 16949 [4,5] urges that top management ensure effectiveness and efficiency for every process determined by their organization. Effectiveness means meeting the planned

activities, whereas efficiency refers to the relationship between achieved results and applied resources [4,5]. The ISO TS 16949 is a very important technical specification for the automotive sector. Therefore, this work will check if companies certified by ISO TS 16949:2009 are also classified as belonging to World Class Levels. If not, it will define the maturity level of those companies by applying the Industrial Benchmarking Questionnaire. This tool was created by the London Business School in partnership with IBM. Together with the Confederation of British Industry (CBI), those institutions have an International Benchmarking Program. After this analysis, results will be compared using an analogy to Boxing to verify the maturity level of those companies, as well as the strengths and weaknesses using the

Grey Correlation Analysis.

The aim of this study is to adapt and apply a script based on MED to diagnose the maturity level of companies certified by the Automotive Quality Management System ISO TS 16949: 2009, in order to verify at what extent those companies are considered WCO, according to the Industrial Benchmarking indicators. This research focus on studying only certified companies by the Automotive Quality Management System ISO TS 16949. Its population will be composed by companies that work with pieces and bulk materials for the Brazilian automotive industry. The sample size shall be of four ISO TS 16949 certified companies and was held until 2013 as several case studies, applying a questionnaire with Practice and Performance Indicators. For data collection, the questionnaire was sent by email to the selected companies' managers.

For many years, technical committees worked to align automotive standards and ISO 9001 into a single system considering the technical specification ISO TS 16949 2009 [5]. The ISO has developed many other standards and some are customized for specific industry sectors such as the automotive, while others are structurally modeled on ISO 9001 [6]. The objective of ISO TS 16949 is to develop a quality management system that promotes continuous improvement, emphasizing on defect prevention, reduction of variation and waste in the supply chain [5]. ISO TS 16949 is an Automotive World Standard, equivalent to the QS 9000, a standard that defines quality requirements for suppliers [7,8] and intends to provide a greater focus on quality [9]. The technical specification ISO TS 16949 fulfills certain practices to ensure a consistent level of product and world class quality. It is reasonable to expect that in the future firms will seek the ISO TS 16949 certification as a marketing tool [1]. This technical specification defines requirements of the quality management system for automotive industry-related products [10,11]. Those involve the design development, production, installation and replacement of automotive-related products [12]. Therefore, it avoids multiple certification audits and provides a common approach for a system of automotive quality management [6]. One of the companies in the study of Curkovic & Sroufe [10] reported additional benefits coming from the ISO TS 16949. It was stated that the company has grown, increased sales, warranty quality, kept current business and improved its corporate image to potential clients. The work of Joshi et al [13] mentions that respondent companies affirm that a high level in quality delivery was only reached when world-class certifications were implemented, such as the ISO TS 16949 and other management systems. The scientific research contributes to identify whether certified companies in the Automotive Quality Management System ISO TS 16949 are recognized as WCO. Also, weaknesses and gaps will be identified in order to allow companies to improve and reach the World Class level.

## 2. Research Method

This is a basic research aiming at scientific progress,

expansion of theoretical knowledge, without the concern of applying it in practice. It is considered a formal research in regard to generalizations, principles, laws and knowledge construction. The method is a theoretical concept, obtained from conceptual discussions in articles, literature reviews and conceptual modeling. Also, we apply the case study, as an empirical work investigating a given phenomenon within a real contemporary context through in-depth analysis of one or more cases. The instrument used is the questionnaire prepared by the IEL / SC for data collection, which was completed by participating companies [14].

According to its goals, this is an exploratory research. As stated by Miguel [15], this approach is applied to generalize results from different groups. Oliveira, Marins and Dalcol [16] affirm that this research is both qualitative and quantitative, as provided by the questionnaire. Qualitative data will be nominal and ordinal. Ordinals refer to data that can be ordered, as satisfaction, possibly classified as: very satisfied, satisfied, not satisfied. Nominal data relate to those answers that cannot be sorted, as car brand, that could be Honda, Ford, GM, or others. Quantitative data will be used as discrete data, which are generated through calculation, such as number of children in a family. The research design is a cross-sectional and observational study, involving data collection from individuals of one or more groups, but without intervention. Observational research will define the target and chosen population for this survey, identifying samples for population and information. The type of sampling plan is the probability sampling applied to Brazilian clusters.

## 3. Theoretical Foundation

### 3.1. Quality Concept

Quality is the degree to which a set of inherent characteristics fulfills requirements and can be characterized with adjectives as poor, good or excellent [6]. Deming [17] states that quality can only be defined by who assesses, because for those working in production, quality is related to their personal performance.

Juran [18] defines quality as fitness for purpose. As he describes, a method to measure is based on the frequency of deficiencies (number of defects, number of errors, number of field failures, rework hours, cost of poor quality) by opportunities of failures (number of units produced, total hours of work, number of sold units, sales revenue), but this measurement depends on the product or service performed, because sometimes the analysis presents great results, but the company is losing clients.

Crosby [19] says that quality is conformance to requirements; therefore, non-conformity is lack of quality. He affirms quality to be tangible and considers it can be measured in costs, divided into assessment, prevention, internal and external flaws: the costs of quality. Also, Crosby introduced the concept of Zero Defects, which is a performance measure aiming to make it right at the first time [19,20]. It is better to

focus on preventing defects rather than just trying to find and fix them. Based on this concept Gan et al [21] says that to meet these requirements for quality, reliability analysis should include both project and operations process. It is also mentioned that quality concepts should be incorporated in the design process, not only in quality monitoring at the operational level.

Nevertheless, Ilkay and Aslan [22] mention that quality should be considered a systematic method aiming to establish a Quality Management System. Las Casas [23] approaches Quality in terms of services, defining it as the ability to provide satisfaction, because it is not enough just to please the consumer, it is necessary to delight him, exceeding expectation in meeting needs, solving problems or providing benefits. Moreover, many organizations are looking for means to improve service quality in order to achieve customer satisfaction [24].

### **3.1.1. Quality Control**

Quality control is defined as a process during which managers evaluate the actual performance, compare it to the former goal and work on those differences. This concept refers to maintaining the "status quo" in order to sustain planned processes so that those remain able to achieve operational goals [17].

Conventional quality control was based on centralized specification or performance known as small quality [18]. Goods were then inspected regularly and high quality products were labeled with special symbols [19].

Note that Quality Control has an equivalent meaning to product inspection [25]. The inspection was applied mostly at the end of the production line, in order to ensure that products sent to the customer had proper quality. Quality control was then performed by using the Pareto Principle, created by Vilfredo Pareto [26].

### **3.1.2. Quality Guarantee**

According to Díaz et al [25], Warranty is usually defined as the policy applied to customers in regard to purchased products or services that could be replaced or repaired in case of any problems over a period after acquired.

The warranty is approved once evidence is provided, but the kind of evidence varies greatly according to claimers and product nature. Regarding natural products, guarantee is defined by vegetable freshness, for example. Nevertheless, manufactured products rely on laboratory-based evidence. According to Crosby [19], Quality Assurance means engaging people, from top management to frontline workers, to improve in every task.

Warranty data correspond to contractual obligations incurred by the manufacturer in connection with a product sale. The analysis of these warranty data focus on seeking new methods to estimate the field of product reliability and register product warranty claims in the company's records [27,28].

### **3.1.3. Quality Management**

According to Zu et al [29], organizational culture is recognized as something that influences effectiveness of the

implementation of Quality Management and companies urge to adopt tools and techniques of quality management if they wish to survive and prosper.

The term Quality Management refers to coordinated activities to control an organization in regard to quality, including the establishment of policies, objectives, planning, control, assurance and quality improvement [6].

To achieve this management level, the ISO 9004 defines principles of quality management related to:

- Customer Focus;
- Leadership;
- Employee Engagement;
- Process Approach;
- Systems Approach to Management;
- Continuous Improvement;
- Evidence-based Decision Making;
- Mutually beneficial relationships with suppliers.

Quality management programs and practices have defined decades of research [30]. Even in the research by Rahman et al [31], the Total Quality Management (TQM) and quality management programs are considered as two different practices. Quality Management practices are designed to guide manufacturing resources and to improve quality through an improved process control (eg, SPC), documentation (eg, ISO 9001), a greater cooperation and engagement (eg TQM), and deeper improvement efforts as by applying Six Sigma concepts and tools [32].

### **3.1.4. Quality Management System**

For Deming [16], a system comprises a set of functions or activities (sub processes, internships, etc.) established for the same purpose within an organization.

A Quality Management System directly controls an organization in relation to quality [6]. As Mahmoud et al. [33] states, in a competitive international environment for economic growth, companies need to constantly adapt and optimize their industrial tools to increase productivity by implementing a Quality Management System.

Levine and Toffel [34] say that the implementation of a Quality Management System in accordance with ISO 9001 documenting operational procedures, training, internal audits and corrective action proceedings. A system implementation relies on its processes capability of providing high quality products and services, but also to its ability on applying continuous and consistent quality improvements in face of changes [25].

### **3.1.5. PDCA cycle**

In 1924, Walter A. Shew Hart added the control charts to the concepts of quality, included statistical concepts to the production reality of the company Bell Telephones Laboratories and also proposed the PDCA cycle, directing analysis and problem solution [23]. According to Fisher and Nair [24], there are few records about how statistical methods were used to ensure quality prior to Shew Hart, who proposed the PDCA cycle and control charts.

Reniers et al and Azadeh et al [35,36] approach the PDCA application with the vision of continuous improvement: the

loop of continuous improvement refers to the systems efficiency; and is also a very important feature for systems integration, according to Azadeh et al [36].

### 3.2. Benchmarking

Organizations tend to imitate the industry best practices in order to improve performance and maintain competitiveness. This requires companies to closely monitor changes in business environment, evaluate new technologies and improve practices in their own industry [37]. Benchmarking was considered one of the most popular management techniques in the 1980s and 1990s and earned a lot of credit helping organizations to improve their competitive advantage [38].

Benchmarking as a technique was developed in the US during the 70s [27], firstly adopted by the Xerox Corporation in this decade [39]. The president of Xerox was concerned with the Japanese companies advance in this market, and decided to send a team to compare his products with its eastern competitors. It was noticed that Japanese products were cheaper though simpler and Xerox began to change their products from that time onwards [27].

To Schefczyk [40], for companies with internal benchmarking, simple cost-based measures appear to be adequate for analysis. Furthermore, Serdar Karaman [41] considers benchmarking as the most powerful approach to performance as it provides a systematic structure to identify, classify and evaluate processes, activities and companies' performance.

#### 3.2.1. Industrial Benchmarking

In the industrial benchmarking, development of new indicators into the process improves business operations and competitiveness [42]. Schefczyk [40] says that the industrial benchmarking can be a way to identify improvement opportunities. The Industry Benchmarking is a tool created by the London Business School in partnership with IBM. Together with the Confederation of British Industry (CBI), those institutions have an International Benchmarking Program and a database with over 1000 companies 34 countries [14].

The Euvaldo Lodi Institute of Santa Catarina - IEL/SC [14] has been accredited by the International Comparison Ltda and aims to apply Industrial Benchmarking in Brazil through a certified network of multiplier institutions. The benefits for those companies include identification of its management strengths and weaknesses, subsidizing investment decisions and providing strategic information on the sector they operate. All information on the company that hires an application of Industrial Benchmarking is kept under strict confidentiality. Individual data will only be disclosed with the company written permission. The company participates in this program as a step towards manufacturing excellence [14].

The industrial benchmarking applies a questionnaire to various areas of the company [43]. The Industrial Benchmarking Survey applied in this study has 80 questions classified into practice and performance indicators, divided

and assessed in each area, as shown in Figure 1.



Figure 1. Areas for Industrial Benchmarking Assessment [14].

The industrial benchmarking analysis should not be seen as an audit, but rather as a process that helps the company to verify its position between world leaders, identifying potential improvement opportunities and strengths. The questionnaire has a scoring system based on intervals 1 to 5 and is transformed into percentages in a graph for analysis [43].

The industrial benchmarking is an evaluation and comparison tool of practices and performances in relation to world leaders [44]. The analysis comparing practice and performance allows the company to prioritize its actions to improve and adapt in order to achieve superior performance [43]. If indicators actually reflect the current situation, real improvement opportunities will be distinguished, but if the evaluation presents an indicator with high grade without a match to a high performance, it may prevent the company to invest in improvements for this indicator. Therefore, when the final indicators are analyzed according to best practice standards and performances, they are also compared with indicators from companies that completed the same process [44,45].

### 3.3. World Class Organization (WCO)

A lot of effort is put into identifying 'best practices' to help companies achieve higher performance levels [46]. According to Laugen et al. [46], these Best Practices have significant effect on high performance companies.

Companies with best practices typically achieve higher production performance than their competitors [47]. Therefore, as Motwani et al. [48] state, many manufacturing companies embraced the philosophy of World Class Manufacturing (WCM), a concept that gathers the best practices.

Voss and Blackmon [49] define practices and performances from world class manufacturing:

- Practice of World Class is the established process, placed in order to improve business execution;
- World Class Performance are measurable improvements in the manufacturing process from the adoption of such practices.

The increasing pressure for continuous improvement and

organizational desire to achieve business excellence, high performance, or to become a World Class Organization, brings an urgent need for companies to take steps for improvement [50]. As Harrison [51] affirms, by adopting World Class practices, business performance will improve correspondingly.

### 3.3.1. Analogy to Boxing

To analyze the company position in regard to its practice and performance levels, it was established an analogy with the skill and performance of boxers, a popular sport in England [40]. The analogy is based on benchmarking studies in World Class Production System developed in Europe by the London Business School (LBS), in cooperation with the group of consultants from the IBM company in England [43].

The graph of practices and performances facilitates the study once general indices are obtained by applying the benchmarking model [44,45]. The company receives the designation according to its position in the diagram of practices (x-axis) and performance (y-axis) [43], followed by an analogy to boxing to characterize the industrial maturity, as proposed by Hanson and Voss [52].

The scale in the performance and practice chart ranges from 0% to 100%. The company position in the graph is defined by the answers to the survey indicators, from which are calculated the general practice and performance indices.

According to Calado [44,45], Seibel [43] and Hanson and Voss [52], each category can be defined in regard to its maturity level as described below:

- The World Class Organization is the one that has achieved a performance and practice level equal or higher than 80% compared to the world class performance pattern. Those are characterized by possessing a large part of the best practices available in the industry and by its competitiveness in the international market. A World Class Company reaches operational excellence and positions itself at the industry forefront, with the condition of competing in the international market.

- Companies in the category "Challengers" are classified as companies that obtained between 60% and 80% in practice and performance rates, but have not reached the World Class level.

- Companies in the category "Promising" present practice levels higher than 60%, but still need to improve performance levels that stand below 60%. These are companies that have invested in modernization and best practice adoption, but have not obtained proper return. The challenge of these companies is to improve their performance through effective use of installed resources. There are two different scenarios: practices were recently implemented and are still in a learning period; practices were implemented and remain operational difficulties due to poor training or improper process adaptation to reality.

- Companies in the category "Vulnerable" present performance levels higher than 60%, but best practices are not installed in a sustainable manner. These are companies that, although present satisfactory results, have a very low rated

practice. Results are inconsistent and its position is very unstable, difficult to sustain over a long term period if competition conditions increase. Some companies with simple processes may achieve superior results once best practices are implemented. In all cases, it is necessary to analyze whether the high performance is being achieved by its process simplicity or if the company is generating costs to offset operational inefficiencies, which reduces productivity. A typical example is when the firm tries to meet the given deadline by dispatching orders through airmail, to compensate for delays in lead time. Another example are businesses that operate with high levels of internal defects, but use the inspection at the process end to avoid defective products to reach the customer. In both cases, company pays for operational inefficiency costs.

- Companies in the category "Counterweights" have practice and performance rates between 50% and 60%. These companies are far behind the industrial excellence and certainly struggle with a real international competition and are typically protected niche markets.

- Companies in the category "Punching Bag" belong to the lowest score group. Companies in this category have a score lower than 50% in practice and performance. Their situation is serious and survival is threatened in an open market economy. In this case, business strategy should assume a survival approach.

### 3.4. The Grey System

The Grey Correlation Analysis (GRA) was first proposed in 1982 by Deng, professor at the Huazhong University of Science and Technology [53]. The Grey System is similar to the black box concept: knowledge contained and unknown in the system is rated and analyzed by the Grey System [54].

The Grey correlation degree is a type of quantitative analysis to evaluate alternatives, a measure of similarity between the discrete data that could be arranged in a sequential order [55]. It provides an alternative approach to identify correlations between factors [56] and focuses on the research object [57]. It is used to describe strengths and weaknesses, as well as the proportion and format of the relationship between factors.

The Theory of Grey System avoids to inherent defects of conventional statistical methods [58]. It evaluates features of multiple performances [59], according to the degree of information. If the system information is fully known, it is called a white system; if the information is unknown, it is a black system; if only partial information is known then the system is called gray. The Degree of Grey Correlation fluctuates from 0 to 1 and is equal to 1 if two sequences are identically coincident.

If the sample data reflect the same mutative situation for two factors, it means their correlation degree is higher, on the opposite, if this situation differs, correlation will be smaller [44,45]. As an example, the combination of three designs (A1, A2, A3) together with the cutting method provides an unique design and situation (A4), a total of four designs as shown in Table 1, with quantitative and qualitative data [61].

**Table 1.** Technical index to evaluate design improvements [59]

Index / Project	A1	A2	A3	A4
X1: The precision degree	90	95	99	99
X2: Investment structure (x\$10.000)	1	5	100	0,1
X3: Cost of labor (x\$10.000)	30	9	9	100
X4: Count rate (number per hour)	2000	1200	60000	500
X5: The area size to be covered	Larger	Big	Larger	Biggest
X6: The degree of difficulty and easily to rebuild	Common	Difficult	Most difficult	Easiest

Numbers are adopted to quantify estimated X5 and X6 in Table 2, where all contents are rearranged quantitatively, placed in a non-linear dimensional standardized method. At the same time, all contents are unified assuming a positive index [59].

**Table 2.** Evaluation Index

Index/Project	X1	X2	X3	X4	X5	X6
A1	90	95	99	99	3,75	5
A2	1	5	100	0,1	2,5	1,25
A3	30	9	9	100	6,25	3,75
A4	2000	1200	60000	500	1,25	8,75

At this point, the optimal proportion of samples is  $X_0 = (1, 1, 1, 1, 1)$ , due to the formula (1), which calculates the absolute difference of the samples  $X_0$  and  $X_i$ .

$$X = \begin{bmatrix} 0,909 & 0,100 & 0,300 & 0,033 & 0,600 & 0,571 \\ 0,960 & 0,020 & 1,000 & 0,020 & 0,400 & 0,143 \\ 1,000 & 0,001 & 1,000 & 1,000 & 1,000 & 0,429 \\ 1,000 & 1,000 & 0,090 & 0,008 & 0,200 & 1,000 \end{bmatrix}$$

**Matrix 1**

Using the formula of the absolute difference matrix  $\Delta$ .

$$\Delta_{ij} = |X_{of} - X_{if}| \quad (i = 1,2,3,4; \quad f = 1,2,3,4,5,6)$$

**Formula 1**

E is the difference in the absolute value of  $x_i$  and  $x_0$  in the Matrix 2.

$$X = \begin{bmatrix} 0,091 & 0,900 & 0,700 & 0,967 & 0,400 & 0,429 \\ 0,040 & 0,980 & 0,000 & 0,980 & 0,600 & 0,857 \\ 0,000 & 0,999 & 0,000 & 0,000 & 0,000 & 0,571 \\ 0,000 & 0,000 & 0,910 & 0,992 & 0,800 & 0,000 \end{bmatrix}$$

**Matrix 2**

Once calculated  $\Delta$  (max.) and  $\Delta$  (min.) it is necessary to define weight, due to the judgment of importance. The weight

represents the degree of information importance and is defined between zero and one, as a variable that belongs to real numbers in the range (0; 1), so that the sum of weights equals to 1 (100%).

The  $\Delta$  (max.) = 0999,  $\Delta$  (min.) = 0 and the known weight of the various indexes ( $w_j$ ): 0.2, 0.2, 0.2, 0.1, 0.15, 0.15. The correlation coefficient is calculated according to formula 2.

$$\varepsilon_{ij} = \frac{\Delta(\min) + \rho \Delta(\max)}{\Delta_{ij} + \rho \Delta(\max)}$$

**Formula 2**

The  $\Delta_{ij}$  is the difference between the absolute value of  $x_0$  and  $x_i$ ;  $\rho$  is the distinction coefficient:  $0 \leq \rho \leq 1$ ;  $\Delta_{\min}$  is the lowest value of  $\Delta_{ij}$ ;  $\Delta_{\max}$  is the highest value of  $\Delta_{ij}$ .

The coefficient is different and assumes a value between 0.1 and 0.5, assigned to the value equal to 0.3, to calculate the correlation coefficient of the third matrix.

$$\varepsilon_{ij} = \begin{bmatrix} 0,767 & 0,250 & 0,300 & 0,237 & 0,428 & 0,412 \\ 0,881 & 0,234 & 1,000 & 0,234 & 0,333 & 0,259 \\ 1,000 & 0,231 & 1,000 & 1,000 & 1,000 & 0,344 \\ 1,000 & 1,000 & 0,248 & 0,232 & 0,273 & 1,000 \end{bmatrix}$$

**Matrix 3**

The correlation is calculated by applying formula 3.

$$r_i = \sum_{j=1}^6 w_j \varepsilon_{ij}$$

**Formula 3**

$$r_i = \begin{bmatrix} 0,153 & 0,050 & 0,060 & 0,024 & 0,064 & 0,062 \\ 0,176 & 0,047 & 0,200 & 0,023 & 0,050 & 0,039 \\ 0,200 & 0,046 & 0,200 & 0,100 & 0,150 & 0,052 \\ 0,200 & 0,200 & 0,050 & 0,023 & 0,041 & 0,150 \end{bmatrix}$$

**Matrix 4**

Once calculated  $R_1 = 0.4048$ ,  $R_2 = 0.5315$ ,  $R_3 = 0.6941$ ,  $R_4 = 0.6624$ , the following set of design evaluation is  $A_3 > A_4 > A_2 > A_1$ . This shows that the  $A_3$  project is the best plan. According to the Grey System, during assessment of six indicators, one can learn that is best option is 'to unify and apply the same size box'.

## 4. Method for Enterprises Diagnosis

### 4.1. Stages of MED

This study performed a business diagnosis by applying the Industrial Benchmarking Questionnaire, from the MED created by Calado [43,44] with only 14 of its 24 stages. Steps and its description are based on the PDCA cycle - Plan, Do, Check, Act.

Plan – corresponds to four steps in the MED:

- Step 1: Set up the theme and the preliminary research proposal to apply the MED. The research will be conducted in

four companies related to the automotive sector and that have the ISO TS 16949 certification. The company analysis will be performed through the Industrial Benchmarking Questionnaire;

- Step 2: Proceed to a review of relevant literature on Quality, ISO 9001, ISO TS 16949, World Class Benchmarking, Industrial benchmarking, Grey Correlation Method in order to align with this research aims;

- Step 3: Apply the case study method in order to collect data from automotive companies;

- Step 4: Initial contact with companies to carry out the diagnosis, explaining them about this research through the Information Sheet and Consent Form. This document states that diagnosis will provide the company an analysis to assist in decision making for process, business and human resources improvements. The final results will be available to the company, preserving its confidentiality;

- Step 5: The research participant is identified, which will collect data from the company, fill out the survey through a self-evaluation and send it to the researcher.

Do - Consists of one step in the MED, which is step 6, as follows:

- Step 6: Information is collected to make a diagnosis through a questionnaire. It is explained to the respondent that this work aims to support decision making. The participant must possess knowledge about company data and ideally, respondents could be the Management Representative, Managers or an employee working at the Quality Management Department. Those shall rate each question from 1 to 5, according to the Industrial Benchmarking Survey.

Check - consists of the MED three steps, as follows:

- Step 7: Elaborate calculations after sending the first completed questionnaire for evaluation of each company, in regard to questions about practice and performance in seven areas of Industrial Benchmarking. Afterwards, companies are ranked according to the Boxing analogy to Benchmarking, to define in which maturity level they will be classified. Strengths and weaknesses of practice and performance indicators will also be identified;

- Step 8: Questions with high performance are selected according to the Grey Correlation Analysis Method for diagnosis;

- Step 9: Underperforming issues are selected according to Grey Correlation Analysis Method for diagnosis.

Act - consists of five steps in MED, as follows:

- Step 10: Present the research results through a report for respondents;

- Step 11: Recall the problem that drove the investigation, performed in order to analyze whether the ISO TS 16949 certified companies were also classified as World Class;

- Step 12: Compare results with this research theoretical foundation;

- Step 13: Elaborate the final research report;

- Step 14: Disclose research results.

#### 4.1. The Grey Method Application for Strengths and Weaknesses Analysis

In this study, the Grey System was applied to describe strengths and weaknesses of four companies from the automotive sector. One area of World Class Manufacturing was chosen to describe the Grey System application in MED: Total Quality. Table 3 shows the combination of 16 indicators when assessed by managers from four different companies.

**Table 3.** Indicators pointed by companies in the field of Total Quality

Indicators	Company A	Company B	Company C	Company D
AD 1	3	5	2	4
AD 6	3	3	3	4
AD 8	3	3	1	3
OC 10	3	3	3	3
OC 5	3	3	4	3
OC 7	3	3	3	3
OC 9	3	3	3	3
Q 1	5	5	3	5
Q 10	5	5	1	4
Q 2	5	3	4	5
Q 3	1	5	3	3
Q 4	5	3	3	3
Q 5	5	5	1	4
Q 6	3	3	1	2
Q 8	3	3	3	4
Q 9	5	5	3	4

##### 4.1.1. Strengths and Weaknesses of the TQM Area

After data from the four companies was analyzed by Grey System in the field of Total Quality, values of  $r_i$  were identified, as shown in Table 4.

**Table 4.** Values from the area of Total Quality

Acronym	R	R value	Indicator
Q 6	r14	0,320	Defects (internal)
AD 8	r3	0,342	Performance measures
OC 10	r4	0,404	Tools for problem solution
OC 7	r6	0,404	Systematic application of Benchmarking
OC 9	r7	0,404	Client guidance
AD 6	r2	0,446	Productivity
Q 8	r15	0,446	Suppliers relationship
Q 3	r11	0,524	Process capability
OC 5	r5	0,531	Employee engagement
Q 4	r12	0,560	Product reliability in service ( external faults )
AD 1	r1	0,561	Customer satisfaction levels
Q 10	r9	0,697	Costs of scrap , rework , recycling ( including second quality )
Q 5	r13	0,697	Warranty costs
Q 9	r16	0,759	Production quality accordance to a new product specification
Q 2	r10	0,844	Models and quality procedures
Q 1	r8	0,872	View of quality

The following set of assessment indicators is: Q6> AD8> (OC10 == OC7 OC9)> (AD6 = Q8)> Q3> OC5> Q4> AD1> (Q10 = Q5)> Q9> Q2> Q1.

Strengths for the field of Total Quality are as follows:



- Vision of Quality (Q1): companies that have mentioned the Mentality of Zero Defects and Total Quality; quality control during processes, quality designed to facilitate manufacture; and that quality is everyone's responsibility.
  - Models and quality procedures (Q2), mentioned that lack comprehensive models for quality management and improvement are reformatted, resulting in the implementation of action plans.
- Weaknesses were calculated as follows:
- Defects (internal) (Q6) show that more than 1% of defect (more than 10,000 ppm) may occur anywhere in the process.
  - Performance measures (AD8): mentioned only compared costs and non-financial measures as a result of the process

performance measures.

## 5. Results

### 5.1. Demonstration of the Calculation for the Boxing Analogy

To demonstrate the boxing analogy, calculation will be shown regarding the Company A.

As the calculations shown Practice and Performance in the field of Total Quality, the table 5 below presents calculations for other fields of Industrial Benchmarking applied to Company A.

Table 5. Fields of Enterprise Diagnosis

Fields of Enterprise Diagnosis	Sum of obtained data from respondent	Sum of possible punctuation	%
Total Quality PR (%)	28	40	70%
Total Quality PF (%)	30	40	75%
Lean Production PR (%)	35	55	64%
Lean Production PF (%)	22	45	49%
Logistics PR (%)	16	20	80%
Logistics PF (%)	10	35	29%
Organization and Culture PR (%)	32	50	64%
Organization and Culture PF (%)	1	5	20%
New Product development PR (%)	36	50	72%
New Product development PF (%)	20	30	67%
Innovation Management PR (%)	22	30	73%
Innovation Management PF (%)	6	10	60%
Environment, Health and Safety PR (%)	38	40	95%
Environment, Health and Safety PF (%)	18	20	90%

To obtain the General Practice and Performance index of Company A, the calculation is the same:  $(28 + 35 + 16 + 32 + 36 + 22 + 38)$ : all values of PR, summing up all data obtained by the respondent relating to PR and then dividing by the sum

of possible scores for PR, calculated as follows  $) / (40 + 55 + 20 + 50 + 50 + 30 + 40) = 207/285 * 100 = 73\%$ .

Table 6 shows the overall rate of practice and performance related to the four companies.

Table 6. Overall rate

Fields of Enterprise Diagnosis	Company A	Company B	Company C	Company D
General Practice Index - PR (%)	73%	73%	69%	69%
General Performance Index - PF (%)	58%	79%	56%	68%

#### 5.1.1. Maturity Level of Enterprises

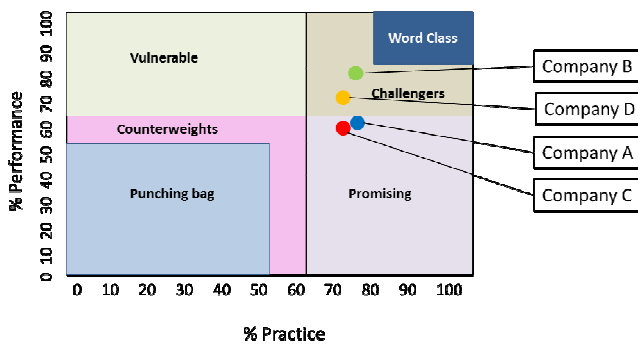


Figure 2. The Boxing Analogy

The maturity level of the four companies is represented in graph (Fig. 2) of the boxing analogy, related to companies A,

B, C and D. The Analogy Boxing graph provided a quick preview, showing at what stage companies are classified according to its a percentage in practice and performance. Also, it allowed a visual way to compare companies in a single graph.

The Boxing Companies A and C in the study were classified as Promising. The companies B and D were classified as Challengers. The companies surveyed are therefore not classified as World Class.

In this research, companies from the Automotive Sector certified by ISO TS 16949: 2009 are not yet classified as World Class, but are close, once this level demands at least 80% in practice and 80% in performance. It was noticed that firms classified as Challengers are closer to getting a World Class rating, while the Promising Companies still have improvements to be implemented in order to achieve this level.



### 5.1.2. Confidence Interval of Surveyed Companies

Note – it was applied a confidence interval of 95% certainty, using Minitab software chart, to affirm Company B actually has better ranking. The same position of other enterprises can be checked in Figure 3.

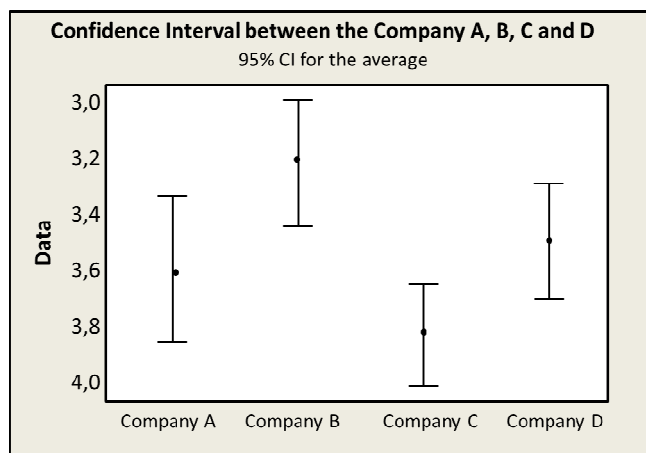


Figure 3. Confidence Interval of 95% for Companies A, B, C, and D.

Companies A and C were classified as Promising, while companies B and D were classified as Challengers. Through these analyzes, we note that the companies in the Automotive Sector certified by ISO TS 16949: 2009 are not yet classified as World Class Organizations (WCO), but are close to this level, once that to be WCO at least 80% must be obtained both in practice and in performance levels. We realized that firms classified as Challengers are closer to getting a WCO rating.

The classification of C as a Promising Company to Company is because it has obtained 73% score in practice and 58% in performance. Generally, that means it needs to management improvement, once the major issue relies in its management method.

Company B was classified as Challengers due to its 73% score in practice and 79% in performance. In general, this means tasks must be improved to achieve its proper results, once the greatest concern is in performing company activities.

The classification of C as a Promising Company for Company C reflects its 69% grade in score and 56% in performance. In general, this means there is a need for improvement in task performance to achieve results, once the greatest concern is in the execution of company activities and its management, since the problem relies in the management practice.

At last, Company D was classified as Challenger with 69% in practice and 68% in performance. In general, this would lead to the same conclusion as for company C.

### 5.2. Analysis of MED

The draft EAW allowed this research design, applying PDCA. It has facilitated this study development, once it showed the step-by-step to be followed. The planning phase is the most time consuming one. After data collection, respondents replied within a few days delay, but without harming research progress. The verification phase was

efficient once the researcher had previously studied about the Grey correlation method. At last, action stage presented a higher complexity due to the need of synthesizing and report findings.

Once the companies' analysis composes a case study, rather than an action-research, data from the four companies was compared in regard to its strengths and weaknesses in general, not on individual basis. To define each company's strengths and weaknesses, the researcher would need more specific information, what was out of this research scope and aims.

#### 5.2.1. Data Analysis for Practice and Performance

It was found that companies have higher scores in practice when compared to performance. This means that these companies are active, applying well-rated activities, methods and tools, but are weak in terms of management. And if those companies do not diagnose its issues, opportunities for improvement will remain unclear.

We note that A and B had the best scores in practice - 73%. Companies C and D obtained values equivalent to 69% in practice. The company that has the best performance is B (79%), and with the lowest value remains with C (56%).

Company B shows that practice, which comprises the applied methods and tools, is on its path towards the best performance. Therefore, among the companies analyzed that is the one presenting the best rating - 73% on practice and 79% on performance.

#### 5.2.2. Comparison Analysis of the Confidence Interval

By applying a 95% confidence interval, almost the same classification was obtained for each company, comparing to the data in analogy to the Boxing chart. Thus, it appears that Confidence Interval graph produced in the Minitab software corroborates with data obtained in analogy to the Boxing chart.

#### 5.2.3. Analysis of Grey Correlation Method

The calculation using with the Grey Correlation method allowed defining strengths and weaknesses, easily performed through the software Excel.

#### 5.2.4. Analysis of Strengths and Weaknesses of Analyzed Companies

Grey correlation method was applied to define strengths and weaknesses for the four companies in analysis, based on the calculation of  $r$  in seven areas of Industrial Benchmarking. Those were obtained through the Grey method calculations for Total Quality, Organization and Culture, New Product Development, Innovation Management, Logistics, Environment, Health and Safety and Lean Production.

## 6. Conclusion

According to this research, the maturity level of companies certified by ISO TS 16949 has not reached a world class level, but stands close to this goal, classified as Promising and Challenging. This would be an opportunity for future work: to verify the maturity level of certified companies in the

Integrated Management Systems. Another project opportunity would be to identify which companies certified in ISO TS 16949 have high defects levels.

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