A POKA-YOKE DESIGN APPROACH FOR THE SOCIAL INCLUSION OF HEARING IMPAIRED WORKERS ON AN ASSEMBLY LINE OF A CAR MANUFACTURING INDUSTRY AT CURITIBA REGION

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Abstract. *The search for quality and productivity has been the basis to differentiate products among different companies at the car manufacturing market, having competitiveness as its goal. At this scenario, the insertion of hearing impaired workers can be a challenging issue. But Brazilian laws demand that up to 5% of the employees – if the company has more than 1000 employees – must be workers with disabilities. In 2008, only about 1% of the workers in Brazil were workers with disabilities, indicating that their inclusion in industry is still a difficult problem. According to the Labor Ministry, from the total amount of workers with disabilities, about 24,65% of them are hearing impaired. Therefore, industries are urged to improve their inclusion of workers with disabilities within their production processes. But, in order to achieve this, industries must design their work stations seeking productivity, employees' safety, and product quality. This work aims to analyze the use of poka-yokes as an instrument of social inclusion at an assembly line of a car manufacturing industry at Curitiba region. That is, the poka-yoke is intended to enable workers with disabilities to perform their jobs with the same levels of productivity and product quality of a – so called – "normal" worker. But, at the same time, hearing impaired workers' safety must be assured. This work presents a poka-yoke design approach focused on assembly line work stations at the studied industry. The approach is composed of a set of rules that must be satisfied in order to fulfill the work station requirements concerning productivity, employees' safety, and product quality. The proposed approach has been validated through a "specialist-panel" (which is a lean manufacturing procedure), a case study, and the house-of-quality procedure (which is part of QFD methodology).*

Keywords: *Poka-Yoke, Automobile industry, Hearing Impaired*

1. INTRODUCTION

Quality and productivity have been major targets for industries that seek an increase on their market share. This is particularly true at the car manufacturing industry, where competition has increased over the last two decades. Under this scenario, the insertion of hearing impaired workers (as well as workers with disabilities in general) at this industry has increased mostly due to governmental laws. Law 8213, from 07/24/1991, article 93, obliges a company with more than 100 employees to have a certain percentage of workers with disabilities among their total working force. If the total number of employees:

i) ranges between 100 and 200, than at least 2% should be workers with disabilities;
ii) ranges between 201 and 500, than at least 3% should be workers with disabilities;
iii) between 501 and 1000, than at least 4% should be workers with disabilities;
iv) is higher than 1001, than at least 5% should be workers with disabilities.

But it has been noticed that many companies do not satisfy such demands and several other problems have been identified. These other problems are related to social discrimination and isolation found at some companies, where workers with disabilities are assigned to the lowest payment jobs and the jobs that require no special training (Godke, 2010). IBGE (2010) indicated that 14.5% of the Brazilian population present at least one disability. According to the Labor Ministry (Ministério do Trabalho e Emprego, 2010), 24.65% of the disabled population are hearing impaired.

The manufacturing environment may present dangers due to the steady stream of transporting parts – with racks of products or subsets of parts. This paper addresses the hearing impaired at a manufacturing environment, the difficulties and challenges for developing their work. Within an environment that requires attention by operators, especially if they are hearing impaired, regarding their safety, the basic premise is the clarity and readability of information. This is provided through a visual communication that is accessible. This is preponderant in the case of hearing impaired people, because they present a more developed sense of sight as a consequence of their hearing loss. According to Costa *et al.* (2010), the transmission of information through visual perception, stimulating interest and attention, is one of the functions of visual communication. Figure, shape and color should be worked together; while color is the first to be captured by human perception. So it is important that a workstation is organized, clearly identified and that signals (or notifies) the hearing impaired operator about his/her duties and dangers; because it brings confidence and assurance that his/her performance does not fall below that of other non-disabled worker. This is the purpose of this research project.

Experiences of inclusion of disabled people in employment, such as in Spain and other European countries, show that although the laws are essential, they are not enough to alter the reality of people with disabilities. It is necessary to overcome prior conceptions and misconceptions about the work capacity of these individuals (Gomez-Allende, 1997).

With the development of rehabilitation techniques and special equipment, people with disabilities are increasingly being enabled for work; and ergonomics has increasingly been used in this area (Iida, 2005). Ergonomics does not pose any difference between the disabled and not disabled worker. So it can be argued that there is no special ergonomy for disabled people; but it can provide specific solutions for certain problems, such as physiological, pathological, transient or other disability problems (Zurimendi, 1994).

Literature presents several articles aiming to improve the insertion of workers with disabilities in industry. Iida (2005) and Simonelli and Camarotto (2005) have analyzed ergonomic issues to enable the insertion of workers with disabilities at production systems. Miralles *et al*. (2007) have addressed the design and balancing of assembly lines. Godke (2010) presented a socio-economic analysis of insertion of workers with disabilities in industry. But no work associating the use of poka-yoke as means for this insertion has been found. Therefore this research has been focused on which poka-yoke requirements can be applied to enable the presence of workers with disabilities at a manufacture working place at a car industry.

This work is justified because human error is to be studied with great concern in the manufacturing environment. They encompass aspects ranging from design of these systems to their operation. For example, an analysis of the last 30 years shows that in aerospace systems the percentage of failures credited to human error ranges from 50 to 75% of the total number of identified errors. But what often has been noted is that most studies aimed at systems reliability has been based on the analysis of machines and their components; and neglecting worker's influence, which has significant importance in production systems (IMAN, 1998). According to Juran (1992), human errors can be classified into: *i*) *Inadvertent Errors* – which are separated as unintentional, unconscious and unpredictable; *ii*) *Technical Errors* – which are caused by lack of competence, skill and knowledge to perform a certain task and can be divided into non-intentional, specific, conscious and unavoidable; *iii*) *Deliberate Errors* – which are fundamentally related to issues of confusing responsibility and communication and can be divided into conscious, deliberate and persistent.

This research proposes to answer the question: Which poka-yoke requirements can be applied to a workstation (at a car manufacturing site) to enable the use of hearing impaired workers at this workstation? Following the criteria of selection of research methods proposed by Yin (2005), this work was developed as a Case Study. The structure of this paper is as follows. Poka-Yoke concept is explained at section 2. Visual devices are introduced at section 3. The proposed approach is presented at section 4. A case study and its results are presented at section 5; while conclusions are presented at section 6.

2. POKA-YOKE SYSTEMS

Poka-yoke mechanisms are also called foolproof, mistake proof, error prevention, fail safe or autonomation devices (or mechanisms). Poka-yoke comes from the Japanese words *yokeru* (which means “proof”) and *poka* (which means “inadvertent mistake”). Such devices have been used since at least half century ago at the Japanese manufacturing industry (Carlage and Davanso, 2001). The poka-yoke concept was proposed by Shigeo Shingo as a way to obtain zero defective parts, eventually enabling the elimination of quality control inspections (Factory Magazine, 1988).

Shingo (1986) made a clear distinction between *error* and *defect*. For Shingo, *errors* are unavoidable because it is not possible for humans to keep a constant level of concentration all the time. Also, instructions are not always understood and followed as expected. On the other hand, Shingo considered that *defects* are totally avoidable and happen when an *error* (not avoided) reaches a costumer. The goal of poka-yoke is to devise the production process in a way that errors can be prevented, immediately detected and corrected. The poka-yoke device is not a quality control procedure itself but a method to detect and prevent errors from reaching the costumer. Instead, its goal is to provide a method to perform 100% inspection of a certain error.

2.1. Functions and types of Poka-Yoke

A Poka-yoke device (within a manufacturing process) has as basic functions the interruption of a production system, the control of pre-established product (or process) features, and signaling when mistakes are detected (Carlage and Davanso, 2001). Successive inspection, auto-inspection and inspection at the source can all be achieved through the use of Poka-yoke methods. Poka-yoke enables 100% inspection through physical or mechanical control (Shingo, 1986). There are two ways in which the Poka-yoke can be used to correct mistakes:

- Control Method – when poka-yoke is activated, the machine or the processing line stops so that the problem can be corrected;
- Warning Method – when poka-yoke is activated, an alarm is started as a buzzing sound or a flashing light seeking to warn the machine (or process) operator.

Poka-yoke of control poses itself as the most powerful corrective device because the process halts until the condition causing the defect has been corrected. Poka-yoke of warning allows the process – that is generating the error – to continue, if operators do not respond to the alarm. The frequency at which the errors occur and the fact that (after an error occurs) they may or not be corrected will influence the choice between these two methods. In general, occasional errors are corrected automatically. More frequent errors generally require a poka-yoke of control. If the error rate is low and if it can be corrected, a poka-yoke of warning is recommended. But, when it is impossible to correct the error, a poka-yoke of control is recommended, despite the error rate. When errors continue to be produced until a human intervention is made, poka-yoke of control is always more effective. In each case, the decision to deploy a poka-yoke must be based on a cost-benefit analysis. Anyway, the poka-yoke of control is always more efficient in most cases (Shingo, 1986). There are three types of Poka-yokes of control proposed by Shingo (1986):

1) The ***contact methods*** identify errors due to the existence or absence of contact between the device and some characteristic related to the shape or size of the product. Sometimes small changes are made on the size or shape of the product, so that errors are more easily identified;
2) The ***fixed-value methods*** determine whether a set of planned activities are performed;
3) The ***motion-step methods*** determine whether the steps or planned operations are followed by a given procedure.

So the first step in the selection and adoption of effective quality control methods is to identify the inspection system that best meets the needs of a given process. The next step is to identify a poka-yoke method (of control or warning) that is able to fulfill the desired inspection approach. Only after determining the appropriate method that one should consider what type or design of poka-yoke device that will be used; that is a contact, motion-step or fixed-value poka-yoke (Shingo, 1986).

3. VISUAL DEVICES

Even with the emergence of advanced communication technologies, Visual Communication remains very useful at the shop floor. A Visual System is a group of visual devices intentionally designed to transmit information at a glance and immediately, without a single spoken word. This is a way to communicate what is needed; more closely to those who need the information and in an accurate and accessible manner; facilitating the day-to-day work; promoting efficiency and making the workplace a pleasant environment (Greif, 1991). According to Santos (2003), visual devices specially designed to transmit information can increase transparency by increasing the visibility of errors and reducing the tendency of its occurrence. Additionally, Grief (1991) indicates that workplaces – where there is efficient visual communication – encourage contact between members on a working site; and, provide a more accurate perception and promote the autonomy of each employee. Standardization is essential to implement a visual workplace in manufacturing. Galsworth (1997) presented a structure to achieve a visually appropriate workplace that has 8 levels of maturity, divided into three stages.

3.1. Classification of visual devices and their degree of control

Visual Devices are classified according to their degree of control. This control depends on the type of message that is sent and the potential risk of non-compliance to information (Galsworth, 1997).

- **Visual Indicator** – it is characterized as a more passive Visual Device where information can be presented on boards or work instructions;
- **Visual Signal** – it is a visual device that draws attention to the message being conveyed, such as flashing lights or warning sirens. A vehicular traffic light is an example of visual signal;
- **Visual Control** – it physically restricts the behavioral decision by indicating its limits. An example of a Visual Control is a shopping cart that visually indicates the maximum volume height;
- **Visual Assurance** – it is the highest degree of control in the process. It is designed to control that only correct actions occur, such as electronic circuits that monitor the door opening. An example of Visual Assurance is a diskette that prevents itself from being inserted incorrectly into the compartment.

The alerts and warnings can be considered a special category of visual devices. They are like visual controls that should alert the recipient about the possibility of damaging occurrences. They can transmit, through signals, information on potential risks, reducing unsafe behavior (Wogalter, 1999). However, these devices do not eliminate the risk, which can sometimes be accomplished with good equipment design, training or Visual Warranties (devices to prevent mistakes). They should be viewed as supplements to security procedures (Moraes and Alessandri, 2002). Some factors influence the adherence to the warnings, including visual pollution, phonograms, colors and the perception of risk. So associating phonograms to colors allow to visually indicate different levels of risk. For example, writing "DANGER" in red background indicates the highest level of risk; and "WARNING" on yellow background indicates a lower risk.

4. PROPOSED APPROACH

This research proposes to answer the question: Which poka-yoke requirements can be applied to a workstation (at a car manufacturing site) to enable the use of hearing impaired workers at this workstation? Following the criteria of selection of research methods proposed by Yin (2005), this work was developed as a Case Study. The approach to the installation of poka-yoke can deal with batch and continuous processes, with a variety of automotive products in the region of Curitiba. It is applied to automotive production lines with low or almost no degree of automation, with operators performing manual operations. Of the various types of possible errors, the approach covers the errors arising from the operations and production processes; and they do not include errors from design and maintenance of machinery or from manufacturing plant design. Regarding Visual Management, since the study addresses production lines with hearing impaired workers, the approach was focused on devices related to the sense of sight. As to visual devices, only Indicators, Signals and Visual Control were used. Alerts and warnings were not considered because they have enough knowledge associated to them; there even exist rules and regulations specific to them.

It is necessary to verify a number of conditions to certify that Poka-Yoke is a proper tool for inserting hearing impaired workers in a production cell. In this section each condition is identified as a step in this process. The proposed approach was divided into 13 steps. It may be noticed that the approach can be inserted into any production system because it presents a broad vision towards the needs of the process; and it has features to social inclusion. The steps of the proposed approach are:

- ***Step 01 – Selecting the item.*** As a criterion for selecting an item to be studied, the cost induced by the non-compliance or quality indicators of the plant can be considered;
- ***Step 02 - The product conforms to the specified standard?*** This is a test where you have to compare the selected item to the standard specified by Engineering. If the item is not in accordance with the standard and there is really a quality problem, you go to the next step. Otherwise, the product is not considered a problem;
- ***Step 03 - Identification of causes.*** In this step, a survey of causes of the problem is performed. A record of the problem helps to better understand the possible causes of the problem. If a record is not available, use quality tools to raise the probable causes of non-compliance;
- ***Step 04 - Problem of Manufacturing or Design?*** A comparison test is done to check if the cause of the problem comes from manufacture or design. Go to the next step if it is a problem of Manufacturing. Otherwise, terminate the study;
- ***Step 05 - The workstation has a hearing impaired worker?*** If yes, move on to the next step. Otherwise, the problem is beyond the scope of the research and concludes the study. From the standpoint of the focus on the disabled worker, if the analysis is finished before step 5, there is no obstacle to the insertion of a disabled worker at this workplace. When conducting the test at step 05 it can be observed that there is non-compliance; and it is necessary to check whether the cause may or may not be the presence of the hearing impaired on the line. If it is not possible to deny it, there will be a need to enable the station to receive the hearing impaired;
- ***Step 06 - The type of inspection is satisfactory?*** At this step initiates the discussion on the elimination of defects when they can be caused by a hearing-impaired. In search of a "zero defects" quality system, one should always match source inspection with the poka-yoke system. The use of poka-yoke methods with self-inspection or subsequent inspection must be limited to technical or financial obstacles. Once you have chosen source inspection, you must control the conditions that influence quality at its origin (Shingo, 1986);
- ***Step 07 - The cause of the defect is of forgetfulness type or other type of human error?*** The vast majority of defects that occur in industry are due to human error. If at the test of this step the cause of failure is human error, go to next step. Otherwise, identify the cause of the error and establish a link with it. Then, fix it with actions such as standardization of the position, training, etc.
- ***Step 08 - The operator can react immediately?*** This step examines whether there is enough time between the the defect detection and the reaction to it. This third question regards to the insertion of the hearing impaired. If that time (of reaction) is greater than the cycle time of the line, the defect is not corrected and the procedure goes to next step. Otherwise, reinforce operator self-control. Self-control is a check by the operator of the entire sequence of operation after its completion. This time of self-checking should be inserted within the cycle time of the operation. This step is important to the insertion of the operator hearing impaired; because the way how he/she will warn that there is an error (and if he can rework the part) will influence to decrease or increase the loss of production. This factor affects the capacity of the workstation to receive a hearing impaired;
- ***Step 09 - The frequency of appearance of error is low?*** Test if the workplace has a strong diversity, above the operator's cognitive and forgetfulness limit. Another factor is the impact of the error in production. If frequency of appearance is low and the error generates great impact, go to the next step. Otherwise check and correct the procedure and specifications of the operation. You should also check the operator's knowledge about the procedure. A high frequency of appearance of the error can characterize a flaw at operation procedure and at engineering specifications to perform the work. Another reason to consider would be the operator training at the station and his/her method of learning at the workplace. A poka-yoke can help the operator to ensure quality when there is no cyclical operation that promotes the break or disturbance of the operation mode. Operator’s concentration may have been affected. For the hearing impaired, which has a greater concentration capacity, a disruption at process flow can cause a failure to detect the error causing a defect. In this case, the Poka-Yoke promotes a rapid and secure error communication ensuring a flawless production;

- ***Step 10 - The design of the device is "simple"?*** Make sure the device is simple to install, effective, suitable for manufacturing, with low cost, and check if the operator is involved in its implementation. If so, go the next step. Otherwise, there is the need for intervention of Engineering;
- ***Step 11 - Communication with the hearing impaired is effective?*** Test if the device signals a noticeable visual error message and that it was easily understood by the hearing impaired. If communication satisfies the disabled worker's needs, go the next step. Otherwise, it is necessary to improve the visual message. This sixth and final question indicates that requirements of poka-yoke with a focus on vision are necessary for the insertion of hearing impaired workers at this workstation. This indicates that priority should be given to colors, shapes and light for the detection and transmission of information to the hearing impaired. This is the most important criterion from the viewpoint of the hearing impaired to perform its function at the post and ensure quality. The faster you get the error information, the faster decision-making occurs by the operator and, consequently, a prevention action is made. Then, whenever the condition of visual communication of the Poka-Yoke is present, the post is eligible to receive a hearing impaired operator. Another important aspect is Poka-Yoke identification at the workplace. One must have an identification device with the photo, the level of system protection (Poka-Yoke of warning, control or interdiction), the situation before and after implementation of the device, the gains obtained with the device and its monitoring plan. All this information contributes to the proper understanding of why there is this device;
- ***Step 12 - Select the appropriate Poka-Yoke.*** According to the method of operation of poka-yoke devices and the device type (if warning or control), check if this is the method that best fits the type of error produced at the workplace (positioning, touch, count or comparison). In choosing the best Poka-Yoke design to solve a problem, a decision matrix can be used, where the attributes considered are: cost of deployment, deployment time and rate of return;
- ***Step 13 - Implementation of the Poka-Yoke project***. Finishing the approach, one has to implement the device that meets the requirements for the insertion of the hearing impaired; and then its results should be evaluated. It is important to have a monitoring plan of the device, checking its validity and repeatability to catch the error; and it is also needed to set how often it should be tested at the start of production. The results will lead to standardization of similar cases.

It is believed that the approach fits in any production system of the automobile industry, be it Toyota, Volkswagen, Renault General Motors. It can be applied in any production system with high human intervention and little automation. Also, it follows a sequence of questions to an efficient installation of poka-yoke, ensuring quality, productivity and safety for the hearing impaired.

5. CASE STUDY AND RESULTS

The study was conducted at an automobile assembly plant of RMC Metropolitan Region of Curitiba. Small vehicles are manufactured in two categories in this line: normal hatch and cross hatch. The selected process is the "welding of the rear right side". This welding operation was chosen because of problems resulting in losses; also for having hearing impaired workers and operations that require high level of attention, in addition to wide human interaction. There were losses due to defective units which were checked before being sent to the next process. All operators have level of skill 3 (what means that operator is able to perform the operation without errors within the cycle time). This process has 18 operators, but two of them are hearing impaired, and a team leader at every shift.

The product (rear right side) involves joining, by means of resistance welding (spot weld), of metal parts which are provided by the company. It consists of the outer and inner plates of the right rear side. After this joining, the fold of outside plate on the inner plate is performed in two steps of 90 ° and 180 ° along the passage of the wheel. From the above information and checking the operation data, it was identified that this workstation originated an error which penalized the quality index of the Vehicle Body Department. At 8 occasions within a week this operation was not performed correctly and the error was only sensed much later, at another site of the plant. The error was due to an incomplete fold operation. Although the folding process is automatic, parts are loaded and unloaded manually by two operators. And this operator can be a hearing impaired person, who was not able to hear the siren that indicated when an abnormal halt of the folding process happened. Table 1 shows the procedures and methods followed by the company for the implementation and validation of a Poka-Yoke device.

5.1. Poka-Yoke validation

To maintain the quality of the Case Study, external validation should be maximizes as means to test the project logic. The characteristic of the case study conducted in a real condition in the automotive industry enabled to test the approach of installing Poka-Yoke to the hearing impaired; and to verify the assumptions made at the beginning of the project. An examination from multiple sources of evidence such as documents, critical analysis of the process flow and operation, and errors mapping has indicated a convergence that determined the requirements to set the best Poka-Yoke to be applied to the proposed situation (case study).

Table 1 - Validation of the Approach in the Case Study.

APPROACH VALIDATION	
APPROACH STEPS	**CASE STUDY**
1- Item selection – Criteria of cost of non-compliance / quality index	08 painted vehicle bodies with incomplete folding operation. Another occurrence 2 weeks later
2- Comparison of the item to the specified pattern	Product not conforming to the specified standard
3- History of the problem: identify the causes	Manufacturing internal problem with no previous record of occurrence
4- Scope of the research: Is it a Project or Manufacturing Problem? If manufacturing, go to next step	Manufacturing Problem
5- Is there a hearing impaired worker at the workplace?	There are 03 hearing impaired workers (02 at 1st shift and 01 at 2nd shift).
6- Type of inspection performed in the clinic? Source inspection, successive inspection (at next the workplace), inspection by judgment / prioritize at source?	The operator is unable to inspect the operation due to the design of the folding device / Inspection at the next workplace (successive) or at next department
7- Cause of the defect is associated to forgetfulness or inadvertent human errors? If yes, continue approach	Hurry can induce the operator to forget and invade the security barrier putting himself /herself at risk. And due to this the bending operation is stopped. Since the operator can not see the error the product goes to the next workplace
8- The operator can react in time between the start, detection and reaction to the error? If not, continue approach	The operator can not react in time, even if he detects the error at the next workplace. The operator can not see if there was error or not at the folding operation
9- Frequency of appearance of the error is low? The workplace has strong diversity?	In this case the workplace does not present a diversity above the operator's cognitive limit and frequency is low
10- The inspection device is cheap and effective in protecting the operator; who assisted in the implementation	The chosen device is easy to install and operators of the module will install it; while electric connections will be set by maintenance personnel
11- How is communication with hearing impaired? Clear visual message?	Light and buzzer alarms will be used to assist both normal and the hearing impaired operators
12- Choose the Poka-Yoke suitable for the application	A Poka-Yoke of interdiction (presence sensor) is used, which will stop the folding in case of invasion and signal that the operation was not completed; indicating that it has to be restarted from where it stopped
13- Implementation of the Poka-Yoke	This same information will be used to standardize a similar process (installation of another Poka-Yoke at Rear Left Side)

5.2. External validation of the approach

In the method proposed by Carlage and Davanso (2001), some aspects and characteristics of organizational culture can be observed, such as: *i*) check whether the problem being addressed can be solved with training; *ii*) greater involvement of management in engagement and motivation during the implementation process; *iii*) multipurpose manpower (when workplace rotation is adopted) and financial resources must be considered in the feasibility of the investment; *iv*) as well as the return on investment regarding the efficacy of the device. From the comparison with the approach proposed in this paper, some aspects can be highlighted as significant to the effectiveness in solving of problem. For example, work teams are responsible for indicating the need to install a Poka-Yoke device; and this need derives from the following aspects:

1- Focus on continuous improvement driven by the method to analyze and solve problems (MASP), and method of analysis and prevention of failures in the process (PFMEA);
2- Focus on prevention and mitigation of risk at work.

In addressing this work, the focus on the need to install the poka-yoke device is a criterion that takes into account various aspects, such as:

1- Cost of non-compliance and quality indicators;
2- If the source of the problem is at Design or Manufacturing;
3- If there are hearing impaired in the workplace;
4- If the proper type of inspection is provided (use of source inspection);
5- The cause of the error is forgetfulness or human error;
6- If the operator can react immediately;
7- Frequency of error is low;
8- Being a simple system and with ability to communicate effectively with the hearing impaired.

The approach proposed in this paper presents a broader focus on the need to install the Poka-Yoke, when compared to the method presented by Carlage and Davanso (2001). It covers more rational aspects as human errors, inspection type, frequency of appearance, severity of the error and design of the device; than simply focusing on continuous improvement, quality and failure analysis. One should beware of the analysis of failures, because the source of these faults may have come from other agents of production and not from inspection. Another aspect that can be compared between the method presented by Carlage and Davanso (2001) and the proposed approach is on how the implementation of the Poka-Yoke device was conducted. According to the method used by the auto parts industry the implementation of Poka-Yoke is conducted by the team leader; who promotes brainstorming meetings, preparation to cause-effect diagrams, data analysis of the operational equipment, analysis of losses and rework of products, control charts and statistical quality control. These methodologies and quality tools are used to find defects, classifying them by different criteria. Such conduct is made when the implementation involves continuous improvement and when it is related to a product under development. There are two different situations to the responsible for team's work; one is a new product which is entering in process and another is process improvement.

The method presented by Carlage and Davanso (2001) presents characteristics related to the culture of auto parts companies, such as training, commitment, changes in workstations and financial resources. One must be careful not to banalize the installation of poka-yoke and how/why it was designed. Do not put a poka-yoke for every type of error which happens. There are different solutions for each type of human error. In this approach, its main feature is to ensure quality, productivity and worker (the hearing impaired) safety. It is independent of the company's culture; it searches for simple and inexpensive solutions to the problem, regardless of organizational or motivational factors.

According to Pahl et al. (2005), a first House of Quality is useful to support the task of converting customer needs into design requirements and identify the highest priority to the client, which belongs to the informational design phase. Using this methodology we can validate the approach to the installation of Poka-Yoke proving that it meets the requirements of manufacturing.

Observing the House of Quality at figure 1, it is verified that once made the correlations among the needs of the client (in this case, a hearing impaired employee and also the quality / technical requirements of the Poka-Yoke), a rating of importance given to the attributes of the device is obtained. This rating indicates that the most important attribute is the signaling ability of the device to than comply to the other attributes; such as the response speed of the signal, the increase of the manufacturing capacity of the line, etc. A more extended analysis of the House of Quality is presented at Silva (2010).

6. CONCLUSIONS

From the analysis of the results, it can be concluded that the main steps to solve the proposed manufacturing problem were considered in the proposed approach to implement a Poka-Yoke in a production line with hearing impaired workers. And through of the Case Study it was possible to test the hypothesis of the research project that the method enables the insertion of the hearing impaired; ensuring productivity, quality and safety to make the workplace dependable. So, in conclusion, the proposed approach is promising for the implementation of Poka-Yoke in automotive production lines with hearing impaired workers.

Another conclusion that the approach provides is that through standardization of the new process the inclusion of hearing impaired workers is feasible. With respect to security, it was found that the same method guarantees the safety for the operator that is either normal or hearing impaired. Since the situation of invasion of the security barrier has not changed, the only change that has happened was the way the communication reaches the operator through a visual message that is clearly and easily with the use of a visual alarm.

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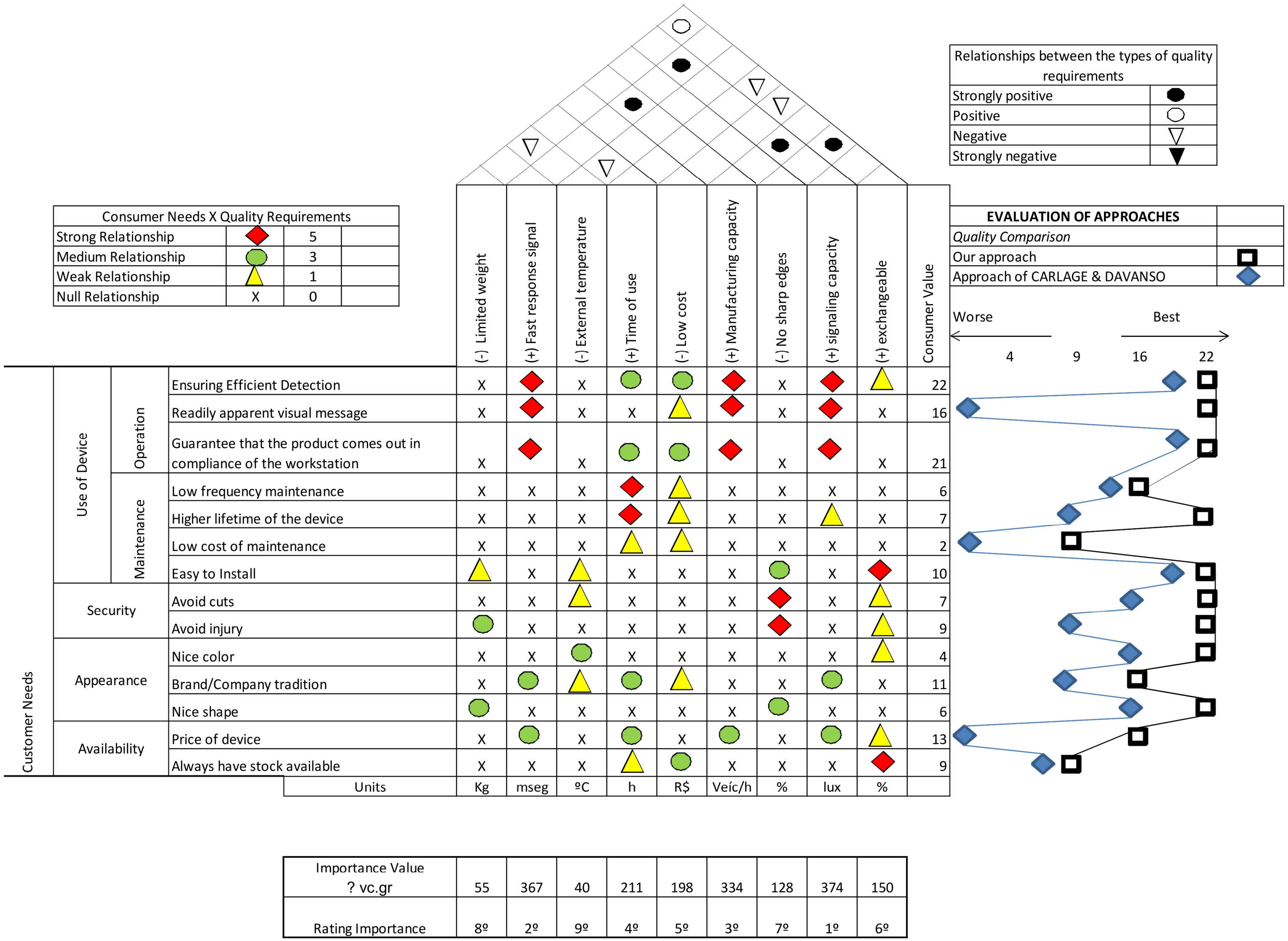

Figure 1. QFD matrix of a poka-yoke device for hearing impaired.