# Industry 4.0 Analysis as Differentiating Factor in Innovation: The Case of an Automotive Industry Using Technology with Optical Sensors to Optimize the Visibility in Cars

*Roberto Carlos Valdés Hernández[1*], José Luis Arcos Vega[2], Juan Gabriel López Hernández[2]*

**Abstract**
An investigation was made in an automotive industry considered as industry 4.0 in the city of Tijuana, Baja California, which is the northwest zone of the Mexican Republic, evaluating optical sensors to optimize the visibility in cars, as the internet of things (IOT) process, to improve the productivity and quality yielding in the manufacturing areas of this industry evaluated. The main objective of this scientific study was the analysis of the operational yielding of electronic sensors used in the industrial operations to count, control and obtain and safeguarding numerical data of parameters of the sensors evaluated as numerical in a data base in a cloud and in a computer system, as an innovation technology. This investigation shows also a correlation analysis of the implementation of innovation system in industrial process of the industry where was made the scientific study, with the evaluation of the operative yielding as innovation with the productivity and quality indices. The correlation analysis was made with the Spearmen method. This was made to determine the levels of impact on the functionality of these electronic sensors on the productivity and quality indices that led to the economic profit factor, as an aspect of innovation, technology and economy in this evaluated industry. The evaluations were with the MatLab software, using statistical methods as the Cronbach's Alpha coefficient and the Spearmen used to evaluate the reliability of the instrument as a questionnaire, with five managers of the industry evaluated about the use of these electronic sensors. The principal objective of this investigation was to determine the principal reason to use the industry 4.0 tools as IOT to improve industrial process in an automotive industry that is a relevant industry in the worldwide. Results shows the importance of the use of this type of industry 4.0 tool.

**Keywords:** Industry 4.0; Innovation; Technology; Internet of Things; Automotive Industry

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## 1. Introduction

The industry 4.0 is a new technological revolution in the industry, where was applied some specialized methods and techniques to increase the warranty of functionality, security and optimization of the manufactured products of the different industries, fabricating with high quality and the required quantity of products manufactured, and also increase the efficiency of the operative yielding of

industrial equipment, machinery and systems and reduce the errors of workers and defective products fabricated (Swat *et al.*, 2014; Jia *et al.*, 2012). This investigation was

made to evaluate the application of the internet of things as a part of the industry 4.0 in an automotive industry of Tijuana, which manufactures complete cars, and where was evaluated the operation of electronic sensors that was utilized to make a function of visibility in cars to avoid accidents, and was

used a computer system to obtain numerical data and stored in a cloud factor. In this scientific study was made a correlation analysis of the use of applications of industry 4.0 and the productivity and quality indices in an automotive industry evaluated (Arsénio *et al.*, 2014). The industry 4.0 supports to any type of manufacturing industry to improve their industrial process and with this increase the productivity and quality levels, with the transformation using the digitalization in the manufacturing areas, where are evaluated constantly the organization and management of the value chain, improving all productive processes. Some time, this can concern to managers and directive people of all industrial companies, because need specialized workers in each part of the manufacturing areas, but when know the potential of what can be produced, is generated a satisfaction to reach any type of goal in the productivity and quality indices (Zhou et al, 2014; Liao *et al.*, 2017).

## 2. Literary Review

### 2.1 Industry 4.0

Industry 4.0 refers to the application of innovation and new technologies in the industry, considering applications such as information in the cloud, artificial intelligence, the Internet of things, interconnectivity processes and automation in industrial processes (Albers *et al.*, 2016; Weber, 2016). These main types of industry 4.0 applications have revolutionized the manufacturing areas of industries of any industry, increasing productivity and quality rates, as well as safety and essentially the economic gains that every industry wants to achieve (Branger *et al.*, 2015; Kagermann *et al.*, 2013). One of the relevant aspects is that the numerical data of the evaluated parameters

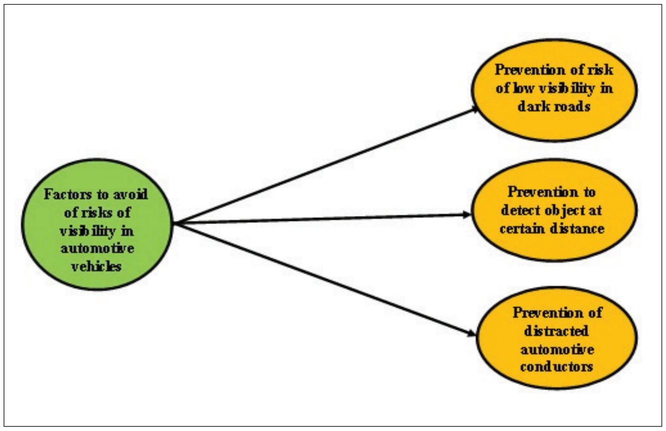
(1) Faculty of Administrative Sciences, Autonomous University of Baja California, Baja California, México.
(2) Engineering Institute, Autonomos University of Baja California, Baja California, México.
*Corresponding author: valdes.roberto@uabc.edu.mx

of the manufactured products, in addition to the operation of equipment, systems and industrial machinery, can be obtained in real time with industry 4.0 applications, one of them being the internet of things This application contemplates from obtaining numerical data and storing them in a database that includes the protection of the data in a cloud, to avoid the use of USB memories (which are rarely used today), or sending them by mail (which is sometimes made a bit difficult by the servers) (Deloitte, 2015). This process also involves the use of electronic sensors, which are the ones that obtain the information from numerical data or measurement levels and send it to a cloud computing system (Bag *et al.*, 2016). Industry 4.0 is recognized as the Fourth Industrial Revolution, made up of innovative technologies, with intelligent systems that can develop a wide variety of activities in industrial processes, substituting labor and avoiding the generation of errors and the presence of products. defective. This has led to reaching the daily, weekly, monthly, seasonal and annual goals of productivity and quality, entering the era of world-class manufacturing industries and the process of competitiveness (Lu, 2017). The decision-making in the application of industry 4.0 tools is very important, for the management of economic, human and material resources; with which the proposed goals are achieved (Colombo *et al.*, 2015; Saldivar *et al.*, 2015).

### 2.2 Automotive Industry

Is an important industry in the worldwide, because are manufactured the automotive vehicles used in the daily activities of people in any type of region of the world (Yan *et al.*, 2015). In this type of industry, are a lot and diverse type of equipment, systems and machinery to supports to workers to make the industrial operations in the fabrication (productivity) and analysis of quality (Hermann *et al.*, 2016). In our country, in the northwest region are some automotive industries that fabricate some parts of cars or complete car, having relevant industrial operations, because debit be high quality in the functionality of cars to avoid any type of accidents, which can generate any type of health symptoms that can be acute or serious (Secinaro *et al.*, 2020). In this type of industry are three principal sensors in the visibility to conductors, being the first an action of perceiving any risk that may arise when driving on roads or highways without artificial light, being in the dark, and may cause an accident (Zhang *et al.*, 2015). The second action may be that sometimes we cannot detect an object at the correct distance and we can cause an accident, and the third may occur when we get distracted by a situation close to our environment and we cannot act quickly. This is expressed in the diagram in Figure 1 (Zhao *et al.*, 2018). The application of the industry 4.0 tools in the automotive industry of any place of the world, and specially in this industry evaluated, is very important because involve a lot methods and techniques about the automatization actions, where was used electronic sensors as the optical sensors analyzed in this scientific study. This generates information with good quality communication, innovation tasks between workers and robotized systems and an increase of the security, efficacy and productivity and quality indices of the products fabricated (Roland, 2014).

**Figure 1.** Prevention factors to support to automotive conductors with optical sensors.




In the three cases, electronic devices such as optical sensors used for rapid visibility in cars are evaluated, generating safety for drivers and passengers. This type of industries forms a great company with actions, as design, development of industrial operations, manufacturing, marketing and sales of products as automotive vehicles as electrical cars (Shaheen *et al.*, 2015).

### 2.3 Internet of Things (IOT)

Is a one type of applications of the industry 4.0 and can be relation with the use of cloud with information obtained with sensors or other types or devices; and is very important in the daily activities, where is a real case in any type of activities, including in the industries installed in the northwest of our country (Liu *et al.*, 2016). For this reason, this is the relevant change in the industry 4.0 to transforms the industrial processes as automatization to the manager of information as a communication process as an innovation and technological aspects (Arnold *et al.*, 2016, Barrios, 2022). This is part of the intelligent systems, which take numerical data of optical sensors as in this scientific study, and stored in a cloud factor. This is taking great relevance actually, because is formed a technology series with the adequate steps to improve apply constantly the continuous improvement every day in industries (De Silva, 2016). This supports to generate a union between the objects to be evaluated and the devices, as is the case of the optical sensors analyzed in this research, where sometimes, by not being properly placed, the Internet of Things process of obtaining optimal information, it can be distorted, and with this, errors can be caused in the operation with car drivers. These types of sensors are connected to cameras, which can observe objects or other cars and make a diagnosis of distance, type of object and possible suggestions through voice, where they are considered as intelligent systems. Another important aspect is to know the operational capacity of the optical sensors, to quickly and easily detect objects that may be near the car we are driving and thus be able to have the possibility, through the Internet of Things process, of obtaining information from functionality of the optical sensors coupled to the cameras in

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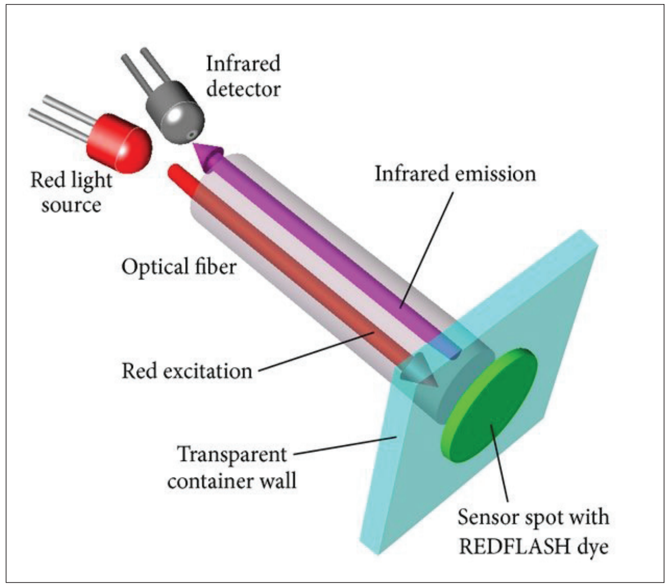
the vehicles and having a relevant database record for the analysis of correlation of variables (Bi *et al*., 2014). In addition, mobile devices such as smartphones or robots connected to a cell phone or computer can be coupled to observe the operation of the optical sensors. With the industry 4.0 can be added good manufacturing practices, to improve the security in workers and the quantity of the products fabricated (Campos, 2010).

**2.4 Optical sensors as innovation process**

These types of electronic sensors have a great function to detect objects at certain distance of automotive vehicles, to avoid any type of accidents and the possibility of any health symptom of persons indoor of cars or outside the cars (Moeuf *et al*., 2017; Cai *et al*., 2014). This sensor is designed and fabricated to make activities at fast and easy operations, and with more diversity of actions to detect. Is utilized in some industrial operations to control some actions and support with the warranty of functionality at high speeds of response (Oliveira *et al*., 2016). These types of sensors have a part, which is called transmitter that receive the signal of detection of objects and a receptor to indicate the presence of the object, fabricated in the same electronic device, and are used in the automatization industrial processes and robotics activities to control with high resolution the industrial operations and coupled to a computer system as a cloud device to store the numerical data obtained in the manufacturing activities and in the function in automotive vehicles (Bandyopadhyay *et al*., 2011). In figure 2 is showed two types of optical sensors as electronic devices, as a procedure of function. The optical sensors have the function of measure the position and movement of objects, to detect any different of the optimal functionality, and are combined with temporizers and efficient match and send a signal to a computer system, store this signal as a numerical data and stored to be evaluate the operative yielding of the optical sensors and the industrial systems, equipment and machinery, which are coupled and utilized in the manufacturing areas (Cheng *et al*., 2016). In all industrial operations, can be applied the simulation analysis to estimate the operative yielding of workers of manufacturing areas, industrial machinery and equipment, and especially in the automotive industry, to increase the operative yielding of workers and industrial systems, equipment and machinery. Some optical sensors as are used in this investigation, emit ultraviolet light and this light reboot in the objects evaluated and receive this light as an electrical signal (Li *et al*., 2013; Miorandi *et al*., 2012).

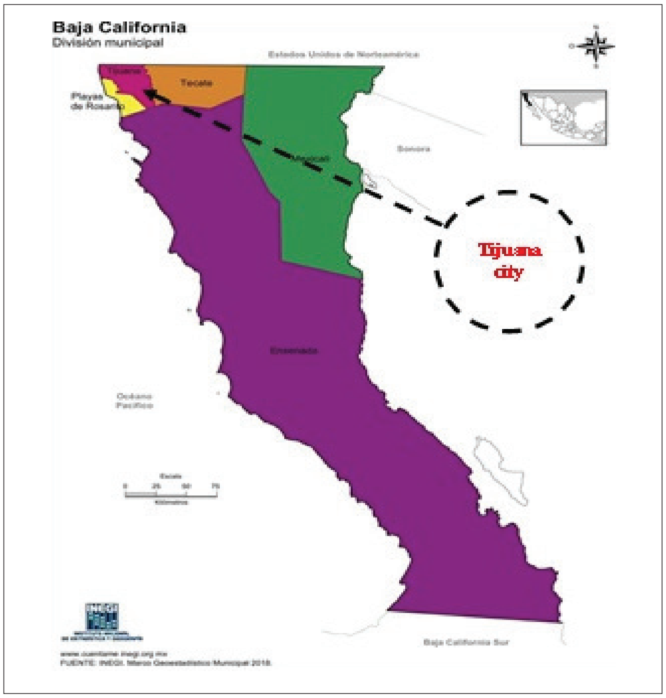
**Figure 2.** Function of an optical sensor.




## 3. The industrial companies in Tijuana

There are many types of industries in this industrial city, where manufactured a diverse products as electronic sensors, biomedical products, metallic structures, automotive vehicles, aerospace parts of aircrafts, cells, televisions, computers; food and beverage and other type of products used in the daily activities. There industries as agricultural, aerospace, automotive, biomedical, electronic, food and beverage, metallic, plastics and textile (IMAQ, 2022). Figure 3 shows the northwest region of the Mexican Republic, where is located the Tijuana city and where was made this scientific study. This industrial city has a lot activities in the manufacturing areas of all industries located in this northwest region of the Mexican Republic, being one of the most important industries, the automotive industry, where fabricated cars with strict specifications and diverse industrial operations are automatized where are used electronic sensors as optical sensors (Hagel *et al*., 2015). This city has some specialized educational institutions and near of Tijuana is located the Mexicali city with some specialized schools too, which have educational programs to specialize students to the industries considered as industry4.0 and these students prepared as specialized professionals generates a lot solution and improvements in these industries located in the Tijuana city.

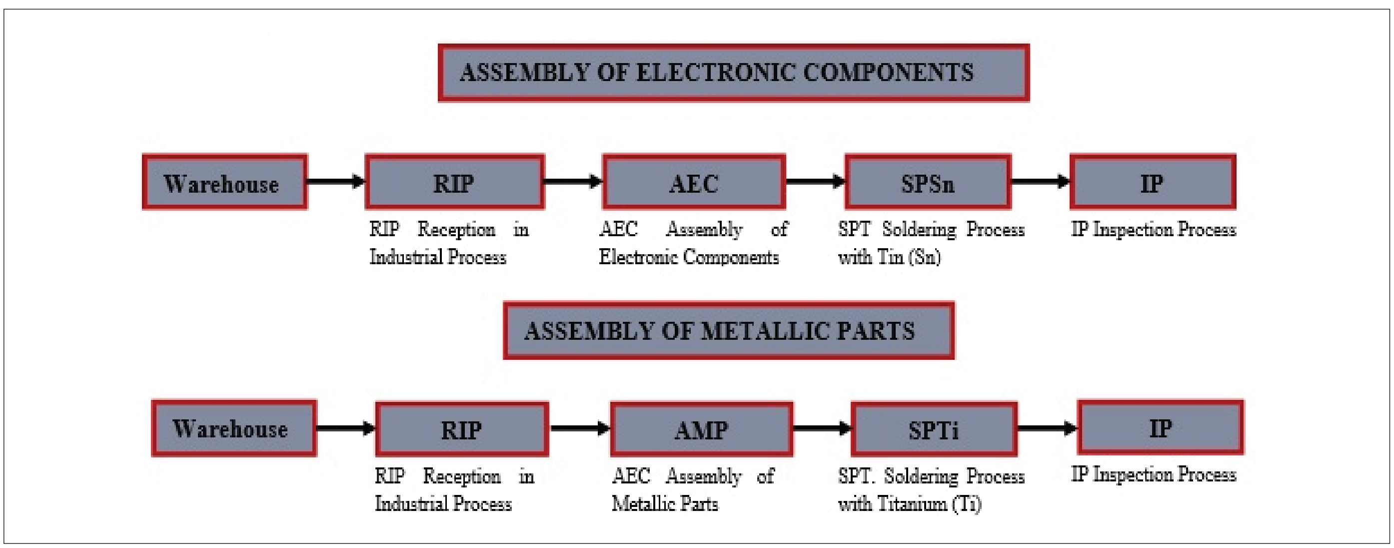
**Figure 3.** Location of Tijuana city, where is installed the automotive industry of this investigation.




### 3.1 Industrial processes in the automotive industry of Tijuana

Some processes make in the automotive industry located in the Tijuana city is a little similar as the processes elaborated in the electronics industry where developed soldering activities with tin to assembly electronic components in electronic boards are. Other processes of the automotive industry of this border city are similar to the metallic industry where are joint metallic parts with soldering of titanium (because resists the corrosion process and can be used the cars in any region of the world) of some sections of the aircrafts (Wang, 2016). For this reason, the processes in the automotive of Tijuana are separated in different buildings, where occurs different problematic situations in the industrial processes and have a negative effect in workers of manufacturing areas, with the presences as diseases as the case of this investigation, but in other times occurs accidents. In both cases, can be a slight negative effect and in other situations it can be severe and can permanently damage operating workers. In figure 4 is showed the principal steps of both industrial processes (Alexopoulos *et al*., 2016).

**Figure 4.** Industrial processes in the automotive industry located in the Tijuana city.




The figure 4 illustrates the two industrial processes of the aerospace industry installed in a zone of the Tijuana city, where is observed that are a little similar, representing only a difference the section of the soldering process where is making with different material, being the soldering process of electronic components with tin and he soldering process of metallic parts (Kusiak, 2016).

### 3.2 The Cronbach's Alpha coefficient

This factor developed in 1951 by Lee J. Cronbach is very relevant in investigations to determine the reliability internal consistency of a scale, that is, to assess the extent to which the items of an instrument are correlated. Experts considers that is necessary the industry 4.0 in the industrial operations, being it's as a principal hypothesis, and with this scientific study was determined the importance of the use of the industry 4.0 tools, as is utilized in this investigation the IOT. In this investigation was made an evaluation of the correlation of use of industry 4.0 tools as internet of things and the positive impact in the increase of the productivity and quality indices. In base of the next factors was analyzed the Cronbach coefficient, which were explained in the next information (Taber, 2018):

**a) Nominal Scale (Qualitative parameter)**. Consists in assign numbers to important factors to any type of investigation that must be evaluated, and may be consecutive or alternate numbers and considering the level of participation of each parameter or degree of influence, for example sex (men and women), being evaluated statistics parameters as frequency, mode and percentages. This process is only to make a difference between the parameters involved in each scientific study.

**b) Ordinal Scale (Quantitative Parameter).** Contemplate assigning numbers to relevant aspects to be analyzed in each scientific study, being important to compare the relation of the relevant aspects considered in each investigation, where is analyzed statistics parameters as median, percentiles and ordinal correlation, for example the analysis of the social class of a person, who could be scaled as:
1 = Low, 2 = Medium and 3 = High.

**c) Interval analysis.** Represents a quantitative evaluation, contemplated as alphanumeric assignment and implied an equidistant quantization of each relevant attribute of an investigation, although the unit of measurement, beings arbitrary since it does not define an absolute zero value, evaluating the arithmetic average, typical deviation, coefficient correlation, test of contrast as Student t distribution.

**3.3 Spearmen analysis**
This evaluation is for analyze the relation between two actions in any activity of this investigation realized in the industrial company where was made this scientific study. This is very relevant, because in base of this analysis is generated the relation of the parameters required in each investigation. This can elaborate with a mathematical process of the statistical equation, called as the Spearmen analysis, which is applied in some activities of different disciplines. The mathematical equation is expressed now (Shadmani *et al.*, 2011):

$$Rs = [1 - (6\sum d^{2)} / (n\ (n^2-1))].$$

## 4. Methodology

The investigation included analysis to determine the level of positive effect of the application of the innovation and technology as internet of things in the increase of productivity and quality indices of the automotive industry of this city evaluated. following the next steps and using the MatLab software, with a methodology correlational and descriptive:

a) An evaluation of the operative yielding of optical sensors used in the industrial process and the relation with a computer system with internet of things process and the stored numerical data of the operative yielding of industrial equipment, system and machinery in the cloud.

b) A correlation analysis of the positive effect of the implementation of innovation systems in the automotive industry evaluated with the productivity and quality indices.

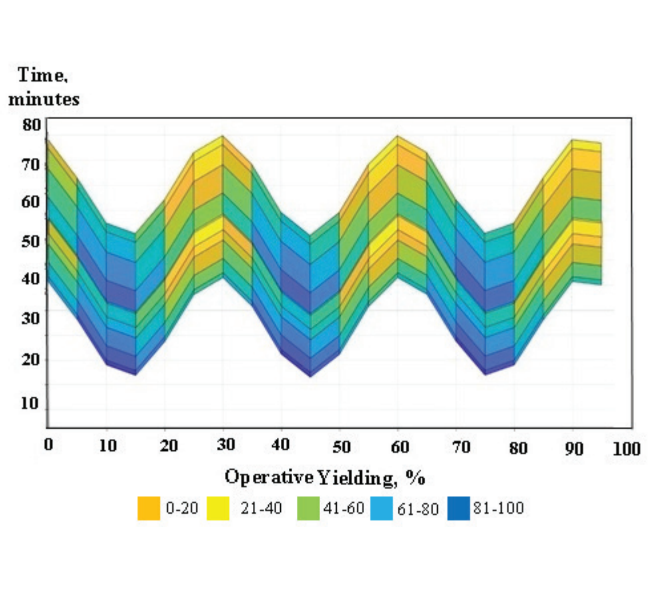
## 5. Results and Discussion

In this investigation was made some type of analysis to determine that is necessary introduce some techniques of the industry 4.0 as was implemented in this scientific study as the internet of things, where was observed the function of electronic sensors as optical sensors in the industrial process of the automotive industry evaluated. In the next sections is illustrated the diverse type of analysis.

### Analysis of operative yielding of electronic sensors

One a relevant aspect in this investigation was made the analysis of the operation of one optical sensor used to improve the efficacy of this electronic sensor coupled to some industrial systems, equipment and machinery; which made the industrial operations, and were coupled to a computer system to obtain the numerical data of the optical sensors and evaluate its operative yielding. This section of this scientific study was relevant as a tool of industry 4.0 with the internet of things, because in base of the function of the optical sensors adapted to the industrial systems, equipment and machinery; was improved the flow process and was increased the productivity and quality indices. With this action used the optical sensors, was obtained the numerical data as information to reach the goals of, which was concerned to managers and supervisors, before make this scientific study. Figure 5 shows the changes of the efficacy of the optical sensor evaluated, where is divided in five sections, observe in each color, where the section 1 is the orange color with efficacy of 0% to 20%, followed of the yellow color with efficacy of 21% to 40%. The next section was illustrated with the green color, represented the 41% to 60% of efficacy, and next is showed the light blue color with an efficacy of 61% to 80% ad finally the dark blue with an efficacy of 81% to 100%. This information was relevant to determine in base of the operative yielding and comparing with the time, and related with the factor of efficacy, because last scientific studies showed the relation of operative yielding with the time and not illustrated the efficacy, and some industrial operations not were efficacy even with the maximum operation yielding, and not increase the productivity and quality yielding. This aspect represented to the automotive industry evaluated, as an important factor of the industry 4.0

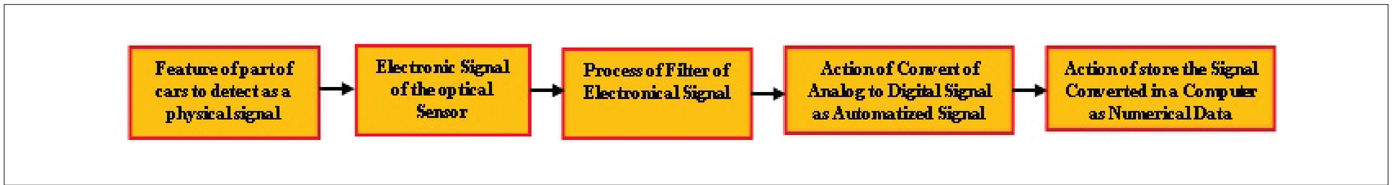
**Figure 5.** Correlation analysis of the operative yielding of an optical sensor and the time of operation (2022).




## Evaluation of acquisition of numerical data by a computer system

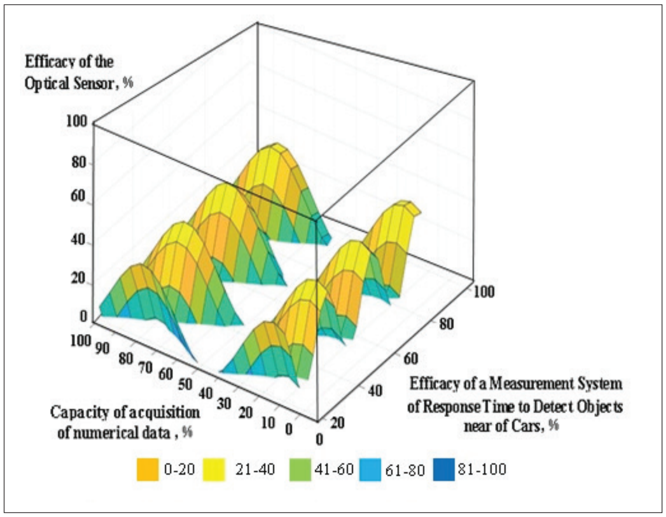
In this section of the investigation was made an evaluation of the computer system that was acquiring the numerical data of the optical sensors coupled to the industrial systems, equipment and machinery. An analysis of the efficacy of the response time correlated with the acquisition capacity and the efficacy of the industrial system used as a meter of the functionality of a specialized detector of objects as an optical sensor that was installed in in front and rear of the cars. The process consisted of the monitoring of the signals of the operation of the optical sensors and the industrial system analyzed, to be converted as the numerical data and stored in a computer system, which is illustrated in figure 6. This figure represented in five steps, was important in this investigation because with this process, can get the electronic signal from the optical sensors and converted to bits as computer information and store in a computer system. The first step was determining a feature of the specific measurement as a physical signal, and then the second step was represented as electronic signal of the optical sensor, to pass to the action of the filter of the electronic signal to have the best clean signal as the third step, and be converted from analog to digital signal as the four step and finally as the last step (five step), was the process of the store of numerical data in a computer system. In this part, was used the PlatformIO, which is a software to the internet of things coupled to the optical sensors and the industrial systems, equipment and machinery of the manufacturing areas of the industry evaluated. This software was used because is very easy to program and have a diverse application to make the programming of any type of electronic sensors.

**Figure 6.** Steps of conversion of electronic signal to numerical data and stored in a computer system.




In base of the process of figure 6 was made an analysis correlated the efficacy of an optical sensor evaluated as a pilot test with the efficacy of the measurement system of response time to detect objects in cars as an action to prevent accidents in the daily life. The third variable involved in this section of this scientific study, was the capacity of acquisition the signals of the measurement equipment coupled to the optical sensors to convert the signals from analog to digital and be represented as bits and numerical data in a computer system. Next is illustrated the figure 7 that shows the correlation mentioned above.

**Figure 7.** Correlation analysis of capacity of acquisition data and an optical sensor with industrial system.



### Evaluation of the productivity and quality levels

The industrial processes used in the automotive industry, where was made this investigation, increased the productivity and quality of the cars fabricated, being important because increased the economic gains of this industry, and being a competitive industry in this region of the Mexican Republic, for the application of high technology of the industry 4.0 tools, as internet of things. With the continuous improvements made, was reached the optimal productivity and quality levels in this industry, improving the quantity and quality of this type of products manufactured, but at the beginning of this scientific study, generated some problematic situations because the adequate methods of the manufacturing are not known, being uncontrolled industrial processes using robotic and automatized systems. Also, in this investigation, made an analysis of the operability of industrial equipment and machinery in this industry, to check the industrial operations and the quality of the cars fabricated, where made the scientific study, to detect any irregular function and take actions quick and correct and improve the production flow and showing this behavior in table 1.

**Table 1.** Analysis of operation of industrial equipment and machinery (2022)

| Factors<br>Month | Time of operation, % | Time of stop, % | Time of corrective maintenance, min | Time of preventive maintenance, min |
|---|---|---|---|---|
| January | 54 | 46 | 30 | 35 |
| February | 59 | 41 | 30 | 35 |
| March | 71 | 32 | 30 | 30 |
| April | 72 | 28 | 25 | 30 |
| May | 74 | 26 | 25 | 25 |
| June | 79 | 21 | 25 | 25 |
| July | 80 | 20 | 20 | 25 |
| August | 83 | 17 | 20 | 25 |
| September | 81 | 19 | 20 | 20 |
| October | 80 | 20 | 15 | 20 |
| November | 85 | 15 | 15 | 15 |
| December | 87 | 13 | 15 | 15 |

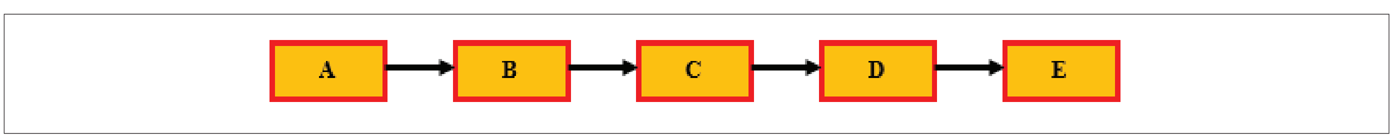
The table above shows the percentage indexes of the time periods, being represented in 12 months of the 2022 year, with four relevant aspects as operating time, downtime (time of stop), corrective maintenance time and preventive maintenance as average periods of each month, of the agricultural equipment and machinery, used in this industry evaluated to the fabrication of cars in the industrial processes in this region of our country. These twelve periods of time show how industrial equipment and machinery operated at the time of preparing the investigation in 2022. In this table, was observed that in the first two months of initiation of the investigation, the operating levels illustrated below 60%, being that in that period, was made the adequate continuous improvements in different process of the industry where was made this scientific study. From the third month of the investigation, being in March of

2022, the indices were higher than 70%, with the month of December of 2022, at the highest level of 87%, showing adequate operability and a continuous flow. The evaluation of the unemployment time indices, at the beginning of the scientific study, became greater than 46%, as shown in January of 2022, and then the percentage was lowing to 13% in this factor in the December of 2022, which caused the production times to increase, and with this a late delivery of the manufactured products generated between each workstation and so on with the customer. Regarding the times of application of corrective and preventive maintenance, levels greater than 25% observed from January of 2022 with 30 minutes for corrective maintenance, and lower as 15 minutes from March of 2022 for preventive maintenance; representing a great waste of time, and with its non-continuous flow, causing delays and sometimes mixing of manufactured products, causing a greater number of errors. With the application of continuous improvement using lean manufacturing tools, the rates of time used by the application of corrective and preventive maintenance reduced, of time of stop of industrial equipment and machinery. Even if, work has continued to reduce these times in order to increase productivity and quality indices and become a more competitive industrial company.

### New system as a tool of industry 4.0

The new system as a prototype proposed as an automated action to detect any situation of critical function represented as a block diagram in figure 8, to control times, increasing the production time and reducing the stop time. This prototype was developed to supports in the increase of the time of the production process, eing very relevant in the increase of the productivity and qualkity levels (Zuluaga et al, 2012).

**Figure 8.** Steps of the automatized system used to improvement the production time of agricultural equipment and machinery in the agricultural industry evaluated.



The robust system contemplated in figure 8, considers the next steps explained now of with each step:

**A) Power supply.** It generates the electrical energy necessary for the automated system to operate in optimal conditions.

**B) Product detection module in correct location using barcode.** It is a system that contains a bar detector module, a component made up of a black space and a blank one that together read the codes and the component that generates the bar code characters.

**C) Showing device.** It is an element that originates from an indicator signal. Being in this automated system, it is a low-intensity light source.

**D) Peer to Peer system.** Components that generate data information through a signal captured from the bar code and sent to a single computerized computer that stores the captured data.

**E) Information storage equipment.** Computerized computer that stores the data captured with the barcode system.

## Evaluation of the impact of the technology in the manufacturing processes

We made an impact assessment using a new technology as an innovation device or system, where in table 2, showing the relationship presented by a computer innovation system, where a computerized process generated to increase the efficiency of productivity and quality levels. This caused an increase in the productivity and quality indices, as shown in the next table. For the innovation operations used the Spyro software, as a platform of a computer system.

**Table 2.** Evaluation of a new technology applied in the manufacturing process (2022).

| Month | Productivity level, % | | Quality level, % | |
|---|---|---|---|---|
| | Without Spyro | With Spyro | Without Spyro | With Spyro |
| January | 65 | 85 | 59 | 87 |
| February | 63 | 83 | 55 | 84 |
| March | 69 | 82 | 50 | 88 |
| April | 70 | 83 | 60 | 84 |
| May | 68 | 87 | 62 | 85 |
| June | 66 | 81 | 64 | 87 |
| July | 60 | 80 | 58 | 83 |
| August | 62 | 86 | 57 | 86 |
| September | 64 | 84 | 53 | 84 |
| October | 61 | 82 | 58 | 88 |
| November | 60 | 83 | 55 | 85 |
| December | 65 | 84 | 57 | 86 |

The table above represents the percentage values of the levels of productivity and quality using the Spyro programming activity coupled with equipment and industrial machinery in the cultivation and crop processes, and used as a pilot test, which was later established for the entire industry where the test. We considered this activity as an innovative system of new technology; showing significant advances and the importance of the application in the automotive industry of the Tijuana city.

## Analysis with the Cronbach's Alpha coefficient

This factor was evaluated as very relevant attribute in this investigation to determine the reliability internal consistency of the scale assigned in the questionary activity to the five managers, illustrated in the next section the questions about the opinion of the industry 4.0 tools, especially the internet of things applied in this scientific study. Once the responses of the five managers who agreed to support this research were evaluated, and two months after the start of this scientific study (March 2022), the same questionnaire was carried out again. Only this time, it was done to the eight managers of the evaluated industrial company, being accounting, engineering, human resources, maintenance, materials, production, quality and industrial safety; showing the result for the good and regular item, without the bad item (because no one answered about this item), in table X, to made the Cronbach coefficient analysis.

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**Table 3**. Analysis of an opinion of managers about the use of the industry 4.0 tools in manufacturing process of the automotive industry evaluated (2022).

| Scale<br>Questions | Good | Regular | Bad |
|---|---|---|---|
| 1. How consider about workers of manufacturing aeras of this industry evaluated about the experience in the information technology thematic? | | | |
| 2. What think about is necessary be constantly training in the information technology thematic? | | | |
| 3. Do you consider if is necessary apply the information technology thematic in the manufacturing processes of this industry evaluated? | | | |
| 4. What think about is necessary invest to the information technology systems and the industry tools as internet of things? | | | |
| 5. Do your considerer that the use of the information technology systems and the industry tools as internet of things have high cost? | | | |
| 6. Do you think it necessary to use industry 4.0 tools in manufacturing processes of this evaluated industry? | | | |
| 7. Do you consider it is necessary to have expert personnel to apply industry 4.0 tools in manufacturing processes of this evaluated industry? | | | |
| 8. Do you think it is difficult to understand the learning of industry 4.0 tools in manufacturing processes of this evaluated industry? | | | |
| 9. Do you consider constantly developing training courses for your personnel in the manufacturing areas on the topics of the use of industry 4.0 tools in manufacturing processes of this evaluated industry? | | | |
| 10. Do you think that with the industry 4.0 tools in the manufacturing processes of this evaluated industry, the productivity and quality indices will be constantly increasing? | | | |

**Table 4**. Evaluation of opinion of eight managers after application of the industry 4.0 tools as internet of things in the manufacturing process of the automotive industry evaluated (2022).

| Items<br>Questions | Good | Regular | Bad | AIT-IOT*<br>Good | <br>Regular |
|---|---|---|---|---|---|
| 1 | 2 | 1 | 2 | 7 | 1 |
| 2 | 1 | 3 | 1 | 7 | 1 |
| 3 | 3 | 1 | 1 | 8 | 0 |
| 4 | 2 | 2 | 1 | 6 | 2 |
| 5 | 4 | 0 | 1 | 8 | 0 |
| 6 | 1 | 2 | 2 | 8 | 0 |
| 7 | 1 | 3 | 1 | 7 | 1 |
| 8 | 3 | 1 | 1 | 6 | 2 |
| 9 | 2 | 3 | 0 | 8 | 0 |
| 10 | 3 | 1 | 1 | 8 | 0 |
| Average (μ) | 22/10 = 2.2 | 17/10 = 1.70 | 11/10 = 1.10 | 73/10=7.3 | |
| Var ($S^2$) | 0.96 | 1.01 | 0.29 | 6.1 | |
| $\sum S_i^2 = 2.26$ | | | | | |

*AIT-IOT. Analysis of action after applied the Internet 4.0 Tool as Internet of Things in the manufacturing process of the automotive industry evaluated.

K: El número de ítems = 3

$S_i^2$: Sumatoria de Varianzas de los Ítems = 2.26

$S_T^2$: Varianza de la suma de los Ítems = 6.1

α: Coeficiente de Alfa de Cronbach

$\alpha = [(K)/(K-1)] * [(1-(S_T^2 / S_i^2)] = [3/ (3-1)] * [(1-(2.26/6.1] = [3/2] * [1-0.37] = 1.5*0.63 = 0.04=94\%.$

As the Cronbach coefficient is 94%, this indicate that the eight managers were agree the use of the use of the industry 4.0 tool as internet of things, because they were observed an increase in the productivity and quality, and for this reason increase the economic gains of the automotive industry evaluated and the bonus of each year for the sales in the may month.

This statistic technique was made in this investigation to determine the grade of relation of the use of the industry 4.0 tool as the internet of things and the productivity and quality indices of the automotive industry, where was made this scientific study. In the table 5 is illustrated the evaluation of the parameters mentioned

**Table 5.** Analysis of operation yielding of ten industrial machines relating the OYBITIOT and OYAITIOT in the manufacturing process of the automotive industry evaluated (2022)

| Factors Industrial Machine | OYBITIOT, % | Hierarchy indices | OYAITIOT, % | Hierarchy indices | Dif=Abs (OYBITIOT – OYAITIOT) | Dif = Abs [(OYBITIOT – OYAITIOT)$^2$] |
|---|---|---|---|---|---|---|
| 1 | 50 | 10 | 68 | 10 | 18 | 324 |
| 2 | 57 | 2 | 75 | 4 | 18 | 324 |
| 3 | 52 | 6 | 72 | 7 | 20 | 400 |
| 4 | 54 | 5 | 74 | 5 | 20 | 400 |
| 5 | 55 | 4 | 78 | 1 | 23 | 529 |
| 6 | 58 | 1 | 76 | 3 | 18 | 324 |
| 7 | 56 | 3 | 77 | 2 | 21 | 441 |
| 8 | 49 | 9 | 73 | 6 | 24 | 576 |
| 9 | 50 | 8 | 71 | 8 | 21 | 441 |
| 10 | 51 | 7 | 70 | 9 | 19 | 361 |
| Total | 532 | 55 | 734 | 55 | 202 | 4120 |

BAITO. Before apply the internet of things tool. Antes de Aplicar la Herramienta Internet de las Cosas de la industria 4.0

AAITO. After apply the internet of things tool. Antes de Aplicar la Herramienta Internet de las Cosas de la industria 4.0

OYBITIOT. Operative Yielding Before Use the Industry 4.0 Tool as the Internet of Things.

OYAITIOT. Operative Yielding After Use the Industry 4.0 Tool as the Internet of Things

**Table 6.** Spearmen analysis of the operation yielding of ten industrial machines in the manufacturing process of the automotive industry evaluated (2022)

| Factors Industrial Machine | Hierarchy indices, OYBITIOT | Hierarchy indices OYAITIOT | Dif=Abs (OYBITIOT – OYAITIOT | Dif=Abs (Dif = Abs [(OYBITIOT – OYAITIOT)$^2$]) |
|---|---|---|---|---|
| 1 | 10 | 10 | 0 | 0 |
| 2 | 2 | 4 | 2 | 4 |
| 3 | 6 | 7 | 1 | 1 |
| 4 | 5 | 5 | 0 | 0 |
| 5 | 4 | 1 | 3 | 9 |
| 6 | 1 | 3 | 2 | 4 |
| 7 | 3 | 2 | 1 | 1 |
| 8 | 9 | 6 | 3 | 9 |
| 9 | 8 | 8 | 0 | 0 |
| 10 | 51 | 70 | 2 | 4 |
| Total | 55 | 55 | 14 | 32 |

BAITO. Before apply the internet of things tool. Antes de Aplicar la Herramienta Internet de las Cosas de la industria 4.0

AAITO. After apply the internet of things tool. Antes de Aplicar la Herramienta Internet de las Cosas de la industria 4.0

OYBITIOT. Operative Yielding Before Use the Industry 4.0 Tool as the Internet of Things.

OYAITIOT. Operative Yielding After Use the Industry 4.0 Tool as the Internet of Things.

$R = \{1- [(6*32) / (10*(10^2-1))]\} = [1-(192/990)] = 1-0.19 = 0.81.$

This indicates that the correlation of the use of industry 4.0 tool as internet of things in this investigation was good correlation, representing that is very important use this relevant tool, as the utilized in this scientific study.

## Conclusions

The use of industry 4.0 tools in the industry of the world is very relevant because generates an increase of the productivity and quality indices, and with this the economic gains, and eliminating the concerns of managers, directive people and specialized persons and supervisors of manufacturing areas. In this investigation was applied the industry tool as internet of things, which generated an increase of the fabricated products of the automotive industry, where was made this scientific study. By the Cronbach coefficient and Spearmen analyses were determine the importance of the use of this industry 4.0 tool, where was coupled optical sensors to industrial systems, equipment and machinery, and also was evaluated the optical sensors used in cars to detect objects and avoid accidents. This tool applied in this scientific study contemplates the use of electronic sensors as the optical sensors utilized, and in an automotive industry as is recognized as worldwide, being relevant because is coupled as a programming system as PlatformIO and Spyro software to control the function of the optical sensors and obtaining the best operative yielding of this electronic sensors and of the industrial systems, equipment and machinery of the industrial company evaluated. With the Cronbach was made the evaluation to obtain the reliability of the instrument of the questionary used with the managers and the Spearman analysis to the analyze the correlation of the use of the industry 4.0 tool as internet of things and the operative yielding of the optical sensors used and ten industrial machines evaluated.

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