Use of Industry 4.0 Concepts to Use the "Voice of the Product" in the Product Development Process in the Automotive Industry

Josiel Nascimento and André Cessa

Abstract The world is going through rapid and deep technological change. With advances due to new uses of the Internet and electronic devices, the relationships between companies and their customers will be improved in a way never seen before. These changes will allow products to communicate with their manufacturers (the Voice of the Product) so that they can be improved in future generations and can also be supported with updates made remotely, without user intervention. Productivity increases, continuous improvement and improved customer relationship are the objectives of this paradigm shift. Products from all durable and non-durable segments will have a high level of customisation, with the customer being responsible for specifying which characteristics will satisfy them.

Keywords Industry 4.0 · Product development · CAN bus · Continuous Improvement · PLM (Product Lifecycle Management) · IOT (Internet of Things) · Connected Products and Services

1 Introduction

The first three industrial revolutions led to mass production, electric energy and the use of information technology making technological competition the centre of economic development. The first revolution, around 1780, involved the use of machines, the second, around 1870, the use of electric energy and the third, around 1969, the use of industrial automation [6]. In the fourth industrial revolution, often called Industry 4.0, the impact will be more profound and exponential as it is built on a set of technologies that allow the combination of the physical, digital and biological worlds. The fourth industrial revolution has the potential to increase economic growth and to alleviate some of the major global challenges we face collectively. We also need

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to recognise and manage the negative impacts it can have on inequality, employment and the labour market.

The impact of the fourth industrial revolution on economic growth is a divisive subject for economists [6]. On one hand, the techno-pessimists argue that the crucial contributions of the digital revolution have already been made and that its impact on productivity is almost over. On the other hand, the techno-optimists say that technology and innovation are at a turning point and will soon trigger an increase in productivity and higher economic growth. They believe that the use of Industry 4.0 concepts will bring a new level of integration and interaction with users and/or customers of any type of service, whether public or private.

The discussion of the potential value and results of use of Industry 4.0 concepts raises the question of creating incentive projects to boost studies and applications, and resume economic growth in Brazil. With this in mind, the Ministry of Industry, Foreign Trade and Services (MDIC) established a working group, called Working Group for Industry 4.0, also known as GTI 4.0, to discuss the subject and create a national agenda. The Group is made up of 50 representatives from government, industrial companies, non-governmental organisations, and so on. The objective is to promote debate on the application of Industry 4.0 technologies for the advancement of Brazilian industry [2, 3].

With the increased popularity of portable, mobile electronic devices and the use of the Internet, both for domestic and business purposes, conventional forms of developing products and services are also undergoing change. It should be noted that there is an increasing number of services on the Internet for the most diverse purposes, from public offices to private financial entities.

Based on these considerations, this case study presents a proposal to change the management of the product lifecycle of a motor vehicle, specifically in the phase of use of the product by the customer, a phase in which today there is usually little interaction between the customer and the manufacturer. Currently, information about the condition of the vehicle and its components is only known at a few specific times from scheduled services, satisfaction surveys and warranty events.

The intention is to propose a change in the current manufacturer/customer relationship that will generate benefits for both parties.

2 Theoretical Reference

According to Piaget's theory of cognitive development, competence is built in the articulation and mobilisation of knowledge by mental processes (physical or mental actions on objects that are modified and become increasingly refined by successive steps of assimilation and accommodation), while the skills allow the competence to be put into action [5]. For example, the skills of a Production Engineer allow them to analyse processes and results, and develop strategies so that they can, through an evolutionary and continuous process, achieve excellence.

2.1 Electronics Embarked on Vehicles

The use of electronics in vehicles has revolutionised the automotive world and considerably increased the number of options available to the market. Electronics has, in many cases, helped to simplify both the manufacture of components and the assembly of vehicles. There are clear technological advances in the automotive environment, ranging from keys that control the ignition to entire systems such as Anti-Lock Braking Systems (ABS) [8] and Traction Control Systems (TCS) [7].

The growing number of electronic artefacts caused the number of wires, modules and connections to increase considerably. The traditional method of interconnecting all the components became a bottleneck since the routing of wires had to be done point-to-point, that is, from the control module to the component that would receive the electrical signal. To help simplify this activity, the systems were subdivided into smaller systems. Figure 1 illustrates the amount of electronic subsystems in an automotive vehicle. (Source: http://telecompk.net/2009/06/30/telematics-in-pakistan/ Accessed on 18/11/2018.)

All these systems are connected by a common physical means called the Controller Area Network (CAN) which manages access to particular functions of the vehicle.

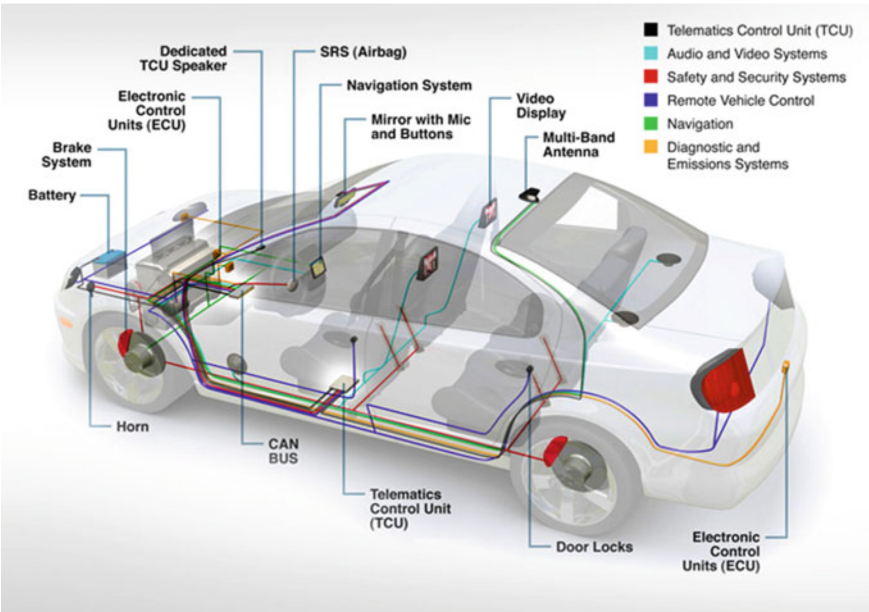

Fig. 1 Subsystems of a motor vehicle

2.2 CAN Network

The CAN network was developed by the German company Robert Bosch and made available in the mid-1980s. Its initial applications were in the bus and truck sectors. Today, it's used among others in the automotive vehicle, ship and tractor industries. With this network, the modules that control the various vehicle systems can exchange information with each other [7].

Module information is shared on the transmission line. The encoding of the information is digital, the data transmission is serial and there is a strategy of priority management in the diffusion of the information in the network. For this, the message that is sent must be in a universal standard. Through this standard, the CAN network is able to define which information has priority to pass through the network [7]. Normally the information that has highest priority is that which groups safety items such as brakes, engine, transmission and air bags depending on the manufacturer's specification. Also, information from the entertainment, comfort and guidance modules, currently called infotainment by the market, travels through the CAN.

2.3 Industry 4.0-concept

The term Industry 4.0 appeared at the Hannover Fair in Germany in 2011. On that occasion employees from Bosch and academics from the German Academy of Sciences and Engineering led a study of the implementation of this industry model for the German Federal Government. Published in 2013, the study addressed the connections between machines, systems, and assets that enable industries to precisely control every step of the value chain to make their plants intelligent.

Some companies use different terms for this type of approach [1]. General Electric uses the term Industrial Internet. Cisco refers to it as the Internet of Everything. The difference between these terms and Industry 4.0 is their application.

According to Gilchrist [1], application in the industrial environment characterises the name of Industry 4.0, whereas Internet of Things also applies to things outside this scope.

For Schwab [6], the question for all industries and companies, without exception, is no longer the question, Will there be disruption in my company? But rather, When will there be disruption? How long will it last? and How will it affect me and my organisation? That leads us to understand that Industry 4.0 is not just a temporary movement, but a trend that is already changing the way we live today.

2.4 Applied Technologies

Industry 4.0, contrary to what many think or imagine, is not only a technology, but a set of Information Technology tools applied to the industrial environment in order to, in principle, improve the production processes and achieve better quality and productivity.

The main technologies are:

- Additive Manufacturing: Also called three-dimensional printing (3D Printing), this is the addition of material in thin layers to form a complete component.
- Artificial Intelligence: A segment of the field of computer science that seeks to simulate human intelligence to reason and solve problems. It can be used by software platforms and robots.
- Internet of Things: Represents the possibility that physical objects are connected to the Internet and can receive and send information, and perform actions.
- Synthetic Biology: A combined effort between various areas of knowledge such as chemistry, biology and computer science for building biological parts, and also modification of existing biological systems.
- Cyber-physical systems: fusion between the physical and digital worlds. This concept can be applied to every object and process in the factory. For a physical object there is an equivalent digital model, called the digital twin.

In addition to the elements mentioned above, there is also the Information Technology architecture that commonly exists in the industrial environment, including components such as data communication networks, computers, servers, Internet and programming languages. Also included in Industry 4.0 are technologies such as mobile devices, Big Data, Analytics and electronic elements such as sensors and actuators.

This range of technologies used together forms what Gilchrist conceptually characterises as Industry 4.0. [1]

The next section focuses on one of these technologies, the Internet of Things.

2.5 Industry 4.0 in the Automotive Industry

The automotive industry is undergoing a profound transformation in both its products and processes. The processes are gaining more and more technology which brings with it a significant improvement in quality and operation time using cyber-physical systems. Cyber-physical systems are those that can be integrated using computer technologies and physical processes [1]. An example of a cyber-physical system is an intelligent assembly line, where the machines can perform several operations by consulting specifications electronically described in the component that is being manufactured, remembering that this all happens in the manufacturing process of the component.

Prototyping using 3D printers, supported by the concept of Additive Manufacturing, also helps to reduce development costs since it is not necessary to develop corresponding tooling. According to Stratasys, it is possible to print from PP (Polypropylene) [12], a type of plastic, to metal in a process called DMLS (Direct Metal Laser Sintering) [11]. In addition to prototypes, small parts can also be 3D printed for emergency repair of machines and equipment.

The use of artificial intelligence can provide gains in all spheres of business ranging from chatbots (which are instant communicators between humans and artificial intelligence technology), through product development, to the use of cognitive systems that try to simulate human reasoning in decision making.

These changes also reach the final product. Motor vehicles are increasingly loaded with technology. The biggest transformations in the on-board technology are due to the high demands of laws and international treaties that demand the reduction of carbon dioxide emissions in the atmosphere and also a demanding consumer market that at all times seeks products that bring convenience and agility to our daily lives.

In addition to meeting legal and market requirements, manufacturers can also benefit from the use of the Industry 4.0 set of technologies by capturing information from their products and then using this information to improve their products.

With the use of sensors and the CAN network, the manufacturer can, through a data connection, capture sensor data and use it to analyse the behaviour of components and systems of the vehicle. Examples include: tracking the number of kilometres travelled; checking fuel quality; remembering the geographic regions travelled; and monitoring of parts that affect safety.

All this information provides the manufacturer with the ability to monitor the product very precisely and even to contact the consumer if necessary in case of an emergency. The information can also be used in a knowledge base for use in continuous improvement and new product development projects.

The product lifecycle has five phases: Ideation, Definition, Realisation, Use/Support and Retirement/Disposal [10]. One of the main challenges for a company is to manage its products from their conception to their withdrawal from the market, in other words, to accompany them from cradle to grave.

2.6 Challenges Faced

Traditionally the main information channels between the manufacturer and the customer have been through car dealers, through the manufacturer's Customer Service Department, and through customer satisfaction research involving direct contact with the customer. All these depend on the presence, availability and commitment of the customer.

The high prices charged by manufacturers for so-called "scheduled services" have driven many customers away from dealerships. As a result, a lot of information about the condition of the vehicle is lost to the manufacturer.

In the case of the customer satisfaction survey, even with a high degree of satisfaction, the customer can refuse to answer the researcher's questions.

In view of the above, it is clear that the manufacturer has only partial access to quality data about its products in the Use/Support phase of the product lifecycle. As a result, when the customer is the main agent in the provision of information, the manufacturer may have the false perception that everything in the product is behaving correctly during use, when in fact the true information has not reached the manufacturer because the information channels mentioned above are not working.

In an attempt to find and trace a new process proposition for this stage of the product lifecycle, several hardware and software suppliers were consulted, in the automotive segment, for initial information gathering.

2.7 Proposed Model

The current model for the product lifecycle has five phases: Ideation, Definition, Realisation, Use/Support and Retirement/Disposal [10].

We propose adding to the current model a feedback flow from the Use/Support phase to the phases of ideation and definition, and inclusion of this information in a knowledge base. According to the Project Management Body of Knowledge (PMBOK), such integration of information from a project may be referred to as a knowledge base of lessons learned [4].

Figure 2 illustrates the proposed model.

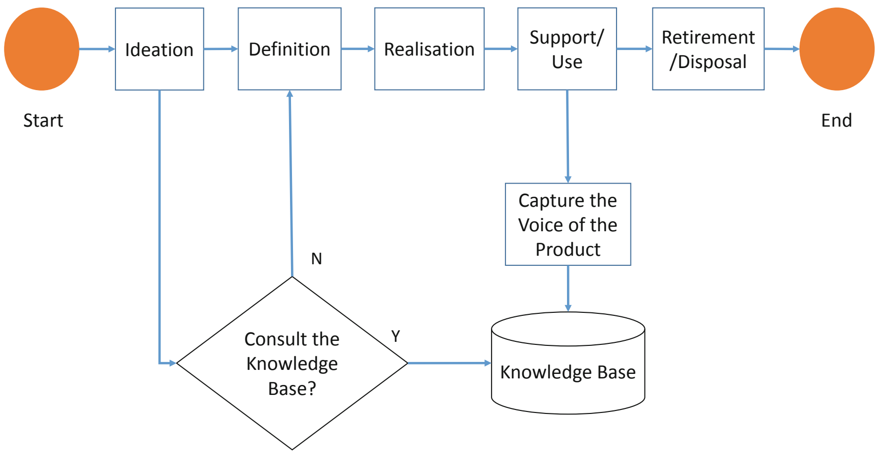

Fig. 2 Phases of the product lifecycle

During the Use/Support phase there will be regular capture of information that will be stored in a database and used as a key decision-making element for new product development activities and for improvement of products already developed by the manufacturer. By analogy with the frequently used term of the Voice of the Customer, this information may be thought of as the Voice of the Product [9].

2.8 Technical Approach to the Objective

As a first step, it's necessary to get alignment between the business expectations and the technical requirements of Engineering, clearly stating which data about the product will be captured.

Then the targeted monitoring points on the vehicle will be evaluated, to identify those which are already monitored. If any components are not yet monitored, a study will be launched to show how best to connect these new components.

For access to the sensors on the components, it is proposed to use the vehicle's auto-radio device, which must have the capacity to access the Controller Area Network to collect information.

Once the equipment provides support for the required function, the manufacturer can develop software applications that will work in background mode (so that the driver/customer will not be aware the software is running) on the car stereo.

When the customer connects their mobile device to the car stereo equipment, or even connects the car stereo to their home network of wireless computers, the applications will start collecting information and send it to the knowledge base (Fig. 2).

To avoid concerns about invasion of privacy, the customer will be informed, through a clearly presented document, that the manufacturer may have access to the information in their vehicle. This document will be kept for later reference in case of any legal dispute, protecting the manufacturer.

The manufacturer will need to know the technical description of all the messages that travel in the Controller Area Network and their respective values so that there is full understanding of these parameters when this information is analysed.

Big Data tools will be used to graphically present information on predetermined parameters, for example, kilometres travelled by the vehicle at the time of a failure. This data will make it possible to make an analysis of the causal factor of the occurrence.

The application that captures this information can also provide it to the customer, for example, informing the customer that the number of kilometres travelled is approaching the value set by the manufacturer for a scheduled service.

With this type of integration into the product, the number of possibilities is almost infinite, transforming the use of Industry 4.0 tools into a strategic and market differentiator.

3 Research Methodology

The methodology used in this case study was literature search.

This type of research offers tools that help in the definition and resolution of problems already known, as well as in directing thoughts and studies to new areas where there is not yet a solid concept.

Literature search also opens up the possibility of a subject being analysed from a new perspective and using other approaches, thus producing new conclusions and results.

Aiming at the implementation of this new "Voice of the Product" approach, the following steps were proposed:

1. Search of bibliographic sources: books, journals, specialised websites and academic publications.
2. Preparation of a proposal.
3. Presentation of the proposal to the Management Board.
4. Running a pilot project with representative production units.
5. Implementation of the new approach in series production.

4 Conclusion

Industry 4.0 has the potential to make processes more efficient and thereby enable the production of products with high quality standards and in a very short time. The number of applications and benefits is almost immeasurable. Many potential benefits can be highlighted: cost reduction; energy savings; increased safety; environmental conservation; error reduction; no waste; business transparency; improved quality of life; unprecedented customisation and scale.

All the above-mentioned benefits add to the consolidation of electronic systems in vehicles, fruit of the third industrial revolution. They enable the automotive industry to expand its research and development centres, encouraging the study of new technologies and their integration into existing and future product lines.

In view of the many possibilities identified during the initial investigation, a proposal was made to develop an automotive vehicle application based on the Internet of Things, one of the technologies of Industry 4.0. Its main characteristic is the capacity of the component and/or product to send and receive information through a data network.

The proposal to implement this new approach was accepted by the senior management of the automotive company in question. At the time of writing this case study, the project has started. It's at the point of selecting technology suppliers. The suppliers targeted would have the "… capacity and openness for technology transfer in order to train the employees involved in the process."

With the total implementation of this proposal it is expected to add competitive edge to an increasingly demanding market. Return of Investment (ROI) is seen not only as the intellectual capital captured by the product, but also the development of a harmonious and trustworthy relationship with customers.

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