# Smart Factory or Smart Car?

## The concept of IoT usability

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*Abstract*— **The subject of this paper focuses mainly on the world car industry and, especially, on how to implement Internet of Things (IoT) technology into the Japanese, German, and U.S. car industries, as well as on differences between the concepts of IoT usability in those target countries. The car industry is now at a difficult phase with regard to how to adjust secret information for car production using open-access IoT technology. Intercorporate relationships provide advantages for car production in general; however, this open-access IoT technology is likely to completely re-arrange these relationships. It will be very interesting to see how these relationships will re-arrange. In this paper, we apply the "smiling curve concept" to find a solution for differences in IoT usability in the target countries. Then, we assess producers' ideas, such as the smart factory in Germany and Japan, and the users' need for a smart car in the U.S.A. As a result, we explain the advantages of intercorporate relationships and how integral parts of the product will be replaced using IoT technology.**

***Keywords-component; Internet of Things (IoT); INDUSTRIE 4.0; Toyota; smiling curve; cyber and physical systems (CPS).***

## I. INTRODUCTION

German car and manufacturing industries are trying to connect their production equipment through the IoT to reduce their inventories, costs and time. These attempts represent the early stages of smart factory, which requires an advanced Supply Chain Management (SCM). Germany is currently ranked third in sales of manufacturing equipment in the world, according to data from Gardner Research in 2015 [1]. This trend is dependent upon the number of cars in production, because car components are made by machines from the manufacturing industries. The existing car industries could shape the former "Lean Production" idea, to reduce inventories [2].

In our work, we conducted a comparative study of producer's and user's viewpoints for car industries. German Volkswagen (VW) and Japanese Toyota are focusing on their production systems. Their production systems are different: VW has a module based production system (Modularer Querbaukasten; MQB) and Toyota has a lean based production system (Toyota New Global Architecture; TNGA). We will not present the details of the difference between the U.S. and the above mentioned European module based production system. The two systems are hypothetically treated as being the same for the purpose of this paper.

Both Toyota and VW have different ways of using the IoT technology. We believe that the parts combination influences the entire idea of IoT usability, which is causing differences between producer's and user's viewpoints. U.S. companies are run by user's viewpoint, for example, through wearable technology such as WiFi, Bluetooth or other connective standards. German and Japanese companies are not run by user's viewpoints, but, rather, VW and Toyota think about the producer's viewpoints, which are much more related to manufacturing special parts combination and the smart factory.

The rest of the paper is structured as follows. In Section 2, we address the question of what a "smart factory" is in Germany, with the INDUSTRIE 4.0 program. In Section 3, we describe the car parts segmentation and smart, connected products that use a similar architecture to that of computer segmentation. Section 4 presents the differences between Volkswagen and Toyota and Section 5 explains INDUSTRIE 4.0 in the Japanese context. The "smiling curve" and the interaction between the cyber and physical space and addressed in Sections 6 and 7, respectively. We conclude the paper in Section 8.

## II. INDUSTRIE 4.0 (SMART FACTORIES)

German car and manufacturing industries are trying to use IoT technology to enhance their competitiveness. The name "INDUSTRIE 4.0" means the upgrade of industrial revolution from 1.0 to 4.0. The first industrial revolution '1.0' followed the introduction of water- and steam-powered mechanical manufacturing facilities in the 17$^{th}$ century. The second industrial revolution '2.0' followed the introduction of electrically powered mass production based on the division of labor between the 18$^{th}$ and the 19$^{th}$ century. The assembly line was introduced on a large scale by the meat-packing factory in Chicago. The third industrial revolution '3.0' used electronics and Information Technology (IT) to achieve further automation of manufacturing in the 20$^{th}$ century. Now, companies are beginning to interactively connect their machinery equipment through the IoT, to improve the industrial processes involved in manufacturing, engineering, material usage, and supply chain as well as life cycle management. This is called the industrial revolution '4.0', which is based on using Cyber-Physical Systems (CPS) by an establishing global networks and common sensors [3].

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CPS make the link between computational Cyber and Physical elements supported by widely used cheap sensors. Recently, the automotive industry is characterized by a static production line. However, German 'INDUSTRIE 4.0' could offer a dynamic production line. Each parts components "Module" will be linked by the sensors mentioned above. This will be a result of producer's viewpoints.

On the other hand, Google made a self-driving vehicle (Physical space). This product uses a CPS scheme. There are different types of sensors such as GPS (Global Positioning System) receiver, Laser range finder, Video camera and Radar. These types of common sensors bring in big data into Cyber space. There is also an interaction between big data in Cyber space and the Physical system. This is why we think U.S. car manufacturing is much more dependent on user's viewpoints.

There is high level IoT planning around the world, such as "Advanced Manufacturing National Program (AMNP)" [4] in U.S.A., "La nouvelle France industrielle" in France, and "Future of Manufacturing" in the U.K. The German "INDUSTRIE 4.0" is also one of these high-level national IoT plans [5]. This high level planning creates a competition between several countries in terms of their technological innovative viewpoint.

## III. Car Part Segmentation and Smart, Connected Products

A car is made up of more than 30,000 parts that can be divided into five broad categories, namely: Engine, Drivetrain, Body, Chassis and Internal/Body Interior.

- The engine is the heart of the car, and it converts thermal energy into mechanical energy.
- The drivetrain transmits the output of the engine to the wheels, via the transmission, drive shaft and differential.
- In general, the body refers to the bonnet, doors, trunk of the car and essentially consists of steel.
- The chassis is currently defined as including the suspension, steering, tires, and wheels.
- The body interior is also an important component of the car, and includes the seats, dashboard, air conditioner, and audio

Cars may be equipped with additional items to enhance their comfort.

Table I shows the different car parts segmentation. VW and Toyota have developed highly innovative production systems that give modularity considerable thought. The term modularity is widely used in studies of technological and organizational systems. Product systems are deemed "modular" when they can be deconstructed into a number of components that can be mixed and matched in a variety of configurations. For example, an internal body "Interior" (each of dash board, air conditioner and audio) forms one packaged "module". This "module" will be linked with a centralized main computer support by widely used cheap sensors.

TABLE I. CAR PART SEGMENTATION

| Car Part Segmentation | I. Engine | II. Drivetrain | III. Body | IV. Chassis | V. Interior |
|---|---|---|---|---|---|
| Toyota | ***Hybrid Electricity*** | Drive Wheels | Bonnet | Suspen sion | Sheets |
| | ***Hydrogen Engine*** | Transmis sion | Doors | Steering | *Dash boards* |
| Volkswagen | ***Down Sized Engine*** | Drive Shaft | Trunk | Tires | *Air Conditioner* |
| | ***Ecofuel Engine*** | Differen tial | | Wheels | *Audio* |

A computer is actually one of the best examples of modular design. The typical modules for this design are power supply units, processors, mainboards, graphics cards, hard drives, optical drives, etc. All of these parts could be easily changeable, so if the parts are used by standard interface, they can be easily replaced.

M. Porter and J. Heppelmann [6] talk about the historical transition of IT into the product value chain. During the 1960s and 1970s, with the first wave of IT, automated individual activities in the value chain used a computer. For example, order processing and bill paying was done through a computer. In the 1980s and 1990s, the second wave of IT-driven transformation included an inexpensive and ubiquitous connectivity to the Internet. The two waves gave rise to huge productivity gains and growth over the economy. However, the products themselves were largely not affected. Then, in the third wave, IT is becoming an integral part of the product itself, with embedded sensors, processors, software, and connectivity in products, coupled with a product cloud in which product data is stored and analyzed. There are called "Smart, Connected Products".

## IV. Volkswagen (MQB) and Toyota (TNGA)

Regarding the concept of "modular design" used in the production system at German VW and Japanese Toyota, we compared, for example, their engine varieties. Table I shows the variety of "I. Engine" module. Here, we notice that Toyota has an advantage of Hybrid engine on one hand, but VW has a competitive edge because of a down-sized engine, on the other hand. This competitive advantage is a product of their inter-corporate relationships. Japanese car producers are characteristically vertically integrated, which is different from an Anglo (U.S. and Europeans) horizontally integrated model. Japanese car producers need, for example, monthly and weekly meetings, which include a variety of other networks such as banks, trading houses, suppliers and customers, which is called "Keiretsu". On the other hand, an Anglo (U.S. and Europeans) model is horizontal integrated. These inter-corporate relationships influence their parts combination for MQB and TNGA.

VW has developed a very innovative parts combination called the Modular Transversal Toolkit (MQB) with their suppliers. They went through a tough period with their production system in the 1980s. MQB was developed under this tough environment. German workplaces are very strictly protected by trade unions, and the existing employee structure created a barrier to change their production system.

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We previously wrote a paper about "German Heavy-weight Management: A Case Study of Volkswagen", which described the potential competitiveness of well-developed German production systems [7].

The MQB system has the engine "quer," or transverse. The "Modularer Längsbaukcombinationasten" (MLB) and "MMB" (Modularer Mittelbaukasten) systems are applied to bigger cars. This development of each broadly formed module such as from MQB, MLB to MMB aims for a more standardization of parts, which is enhanced from the economical and mass markets products to the a middle luxury class to reduce the cost and assemblies.

Basically, Toyota has a long time value chain, which is a tightly coupled production system. The client's diversification led to environmental changes by Toyota New Global Architecture (TNGA). This new platform realizes optimal design freedom and ergonomics. The TNGA provides a foundation for grouping development, which enables the standardization of parts and components across different models, such as VW's parts combination developments, improving the efficiency of the development process while reducing costs.

## V. INDUSTRIE 4.0 (IOT) IN THE JAPANESE CONTEXT

Another question is how to find the best matching point between the standardized (MQB) and elaborated components (TNGA) for each type of integration. U.S. and Germany have created several types of consortium, such as internal combustion, robotics and others etc. U.S. and Germany are very well organized horizontally in terms of their knowledge cooperation among government, industry and academia, not like Japanese vertical intercorporate relationship. This is both good and bad at the same time. Wiener says, "These advantages would seem to be the ability of the brain to handle vague ideas, as yet imperfectly defined." And "Render unto man the things which are man's and unto the computer the things which are the computer's [8]."

## VI. SMILING CURVE

The founder of Aser.co, Stan Shih [9] argued the concept of the "Smiling Curve" in 1992. This theory is about appropriate value added of different sections in the industry. Figure 1 below shows the "smiling curve".

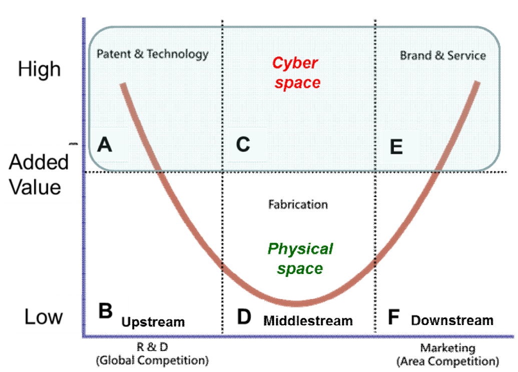


Figure 1. Smiling Curve.

A smiling curve is an illustration of value-adding potentials of different components of the value chain in an IT-related manufacturing industry.

The concept of "Competitive Advantage" written by M. Porter in 1985, gave the concept of the "value chain" [10]. The primary activities in the value chain are: 1. Inbound Logistics 3. Operations 4. Outbound Logistics 5. Marketing & Sales and 6. Service. Also, support activities include: A. Firm Infrastructure B. Human Resource Management C. Technology Development, and D. Procurement. Porter suggests that a firm might develop a competitive advantage in any one of these areas; 1 to 6 and A to D.

The value chain command higher values added to the product (such as Patent & Technology, R&D and Brands & Service) than the middle part (such as Production) of the value chain. Also the Fabrication part could be divided between many different shops, such as paint, assembly, body and so on.

The basic structure of the "Smiling Curve" in Figure 1 from left to right on the horizontal axis, is the upper, middle and downstream of an industry, that is, the component production, product assembly and distribution. The vertical axis represents the level of value-added. In terms of market competition type, the left side of the curve is worldwide competition whose success depends on technology, manufacturing and economy of scales. On the right side of the curve is regional competition. Its success depends on the brand name, marketing channel and logistics capability.

In Figure 1, the "Smiling Curve" explains, from left to right on the horizontal axis, which is labeled A, C and E on this diagram called Cyber space. In this area, we could add a high value virtually, such a patent and idea of technology. This sphere contains intellectual properties, such as Software.

The bottom part of the conceptual diagram, labeled B, D and F, shows what is called the "Physical space" . This area gives a limitation for the added value to physical existence, which is a real product. A good example is assembled car products, in this context.

## VII. INTERACTION BETWEEN CYBER AND PHISICAL SPACE

In this paper, we applied the concept of "smiling curve" to car manufacturing industry. The way the automotive industry uses modular production in today's global competitive environment is similar to the way computers are produced. IoT usability is different between Japanese and Anglo (U.S. and Europeans) countries in terms of the car industry. We discussed about two different types of intercorporate relationships, which are the Japanese ("Keiretsu"= vertically integrated system) and Germans-U.S. type (horizontally integrated system).

Figure 2 positions the targeted countries U.S., Germany and Japan on the "Smiling Curve". The figure shows the Japanese "Keiretsu"= vertically integrated system and Anglo (U.S. and Europeans) type horizontally integrated system, as well as IoT usability in producer's and user's viewpoints.

Assembled car products are mainly made from German and Japanese car producers. Therefore, we think that the

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German and U.S. viewpoint for the car industry are different in terms of using the IoT technology. Japanese and German car producers are focusing more on the physical way for assembly production line out of their module (parts combination) into the real world, using the IoT technology. This plays a very important role for their supply chain management (SCM) such as "Keiretsu" and Anglo horizontally integrated system [11].

## VIII. CONCLUSION

In conclusion, in this paper, we emphasize the different concepts of IoT usability in targeted countries such as Japan, Germany and U.S.A. German and Japanese car producers are more focused on factory management using IoT technology. Germans as well as U.S. place considerable emphasis on user's viewpoint, which means using a car more as an equipment. The car is comparable to a computer, collecting information through IoT (common sensor) technology. Then, we see how the highly developed U.S. user's viewpoint could combine with Japanese and German producer's viewpoint to find out innovative products for smart factories, which is now required.

Google is now trying to make a complete self-driving vehicle without the necessary knowledge of car production.

They have much more IoT based knowledge for car production. Japanese and Germans are adopting this self-driving technology in a stepwise manner, introducing it into their production line, which is needed for the interaction between Cyber and Physical space.

We conducted a module based production system MQB of VW and the other lean based TNGA. The three largest U.S car manufacturers develop their advantage on the production method by using the Smart Factory (big-data) idea. "Smart" means to use "big data", and use it in an intelligent manner.

The meaning of a competitive advantage has been changed with this newly developed relationship with regard to the whole transport environment system.

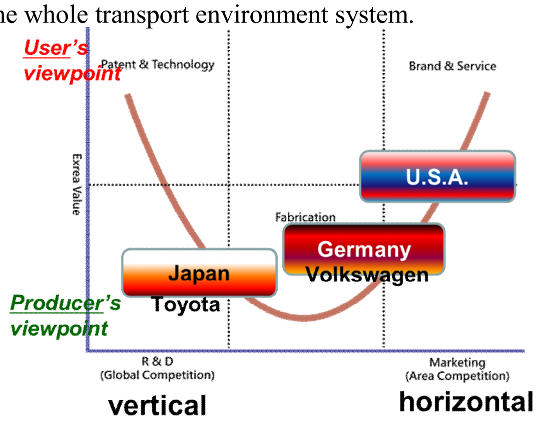


Figure 2. Positions of Japan, Germany and USA on the Smiling Curve

Japanese and German manufactures get their competitive advantage from their intercorporate relationships, not from drivers as user's point of view. However, Japanese vertical ("Keiretsu") model and Anglo horizontal model are substantially developed. As we've discussed by the "Smiling Curve" and CPS, one could make the link between computational Cyber and Physical elements supported by a wide use of cheap sensors. A car becomes a sensor and could re-arrange the total transportation environment.

"Keiretsu" vertically integrated system has produced TNGA. Germans-U.S. horizontally integrated system has developed MQB. Therefore, there is a lot of high level IoT planning around the world. In the car industry, both user's and producer's viewpoints have advantages and disadvantages. However, a horizontally integrated system is far more advanced than TNGA in terms of cyber space connectivity. Modules are developed following the computer based architecture. Such integral parts of the product will be replaced using IoT technology.

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