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A Review on Quality Management System and Artificial Intelligence Methodology in Autonomous Vehicle Development

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A Review on Quality Management System and Artificial Intelligence Methodology in Autonomous Vehicle Development

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Abstract. Quality management is required in the development of autonomous vehicles because the integration between software and hardware is more complicated compared to conventional vehicles. The potential risks arise due to it is challenging to identify some failures in the early stage of the product development process. In addition, some researchers are lack in terms of quality management knowledge, limited resources and information to develop the autonomous vehicle. Different quality management systems and standards related to autonomous vehicles are introduced and compared in this study. This study presents a simplified product development process that integrates between the process method, failure mode, and effect analysis methods. This study also introduces a review of the artificial intelligence approach into this process.

1. Introduction

Human errors including driver inattention, distraction, reckless driving, and poor driving skills, are the reasons for people seriously injured and dead in car accidents. Vehicle malfunction and environmental circumstances are the other reason for vehicle accidents. [1]. One of the main recent trends in research is that fully autonomous vehicles aim to replace all current driving tasks [2]. It highly relays on software and vehicular networks to automated drive vehicles on the road [2]. Autonomous vehicles face safety and security challenges. However, they play a significant role in improving the safety of transportation systems [1]. The software system's malfunction is critical for unacceptable harm to the software system, hardware and most crucial to the safety of human beings [3]. Including the safety aspect into the development process and full compliance with procedures and standards are essential for developing autonomous vehicles [2], [4].

This paper provides a review of quality management systems and quality tools used in autonomous vehicle development. This paper also discusses the integration between artificial intelligence and quality management system (QMS). An overview of a simplified process is presented that aimed to identify and deploy customer requirements, improve the autonomous vehicle's performance and finally satisfy customers.

2. The latest quality management systems of autonomous vehicle

The widely used QMS standards in the automotive industry are ISO9001 and IATF16949. They focus on the overall quality management system. Obviously, the development of autonomous vehicles also under these frames. In order to ensure the safety, function and security, the specific standards, for example, ISO26262, Automotive SPICE, TISAX and SAE J3016, become more critical. They are applied for functional safety, software process capability, information security respectively. All 6 standards are reviewed in this chapter.

2.1. ISO9001:2015, IATF16949:2016

ISO9001 is the world's widely recognized quality standard that provides fundamental concepts, principles, vocabulary and processes for quality management systems (QMS). It also provides the foundation for other QMS standards, for example, IATF16949. This international standard aims to help organizations realize their objectives, create an ability to consistently provide products and services that meet customer and other requirements, enhance customer satisfaction, address risks and opportunities, and demonstrate conformity to related requirements [30],[31].

In the automotive industry, the dominant quality management system is IATF16949 (Former version named ISO TS 16949:2009). It is based on requirements from ISO 9001:2015. A survey shows that there were 62944 ISO TS 16949 certificates worldwide in the year of 2015 and the vehicles then contained embedded software systems [4]. The latest IATF16949 released in the year of 2016 accompanied by the increasing of software-based functional features like autonomous driving capabilities and advanced driver assistance systems. This standard should be applied throughout the whole supply chain. In considering software systems and subsystems are finally integrated into the vehicles, all software also needs to meet at least a part of IATF16949 requirements. This newly released standard adds many requirements in order to control the software quality [32], [36]. Examples of software-related items shown in Table 1. As a part of IATF16949, FMEA also partly adopts the risk assessment methodology of ISO26262. Nevertheless, this paper does not elaborate on the detail of FMEA.

Table 1. Software related sections in IATF16949:2016.

Section	Description
8.3.2.3	Use a quality assurance process for products with internally developed embedded software. The software development process shall be assessed with a specific methodology. Using prioritization based on Risk and potential impact on the customer, Record software development capability self-assessment.
8.3.3.1	Embedded software requirements input shall be identified, documented, and reviewed in contract review.
8.3.4.2	Within the design and development validation phase, embedded software within the system of the final customer's product should be evaluated.
8.3.6.1	Document the revision level of embedded software and hardware as a change record.
8.4.1.2	The supplier selection process shall include an assessment of software development capabilities.
8.4.2.3.1	Extend the 8.3.2.3 requirements to suppliers.
9.2.2.1	The organization shall include software development capability assessments in the internal audit program.

2.2. ISO26262, Automotive SPICE

The International Electrotechnical Commission (IEC) study not only on hardware but also on software. IEC61508 (Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems) approved by IEC as an international standard that uses a risk-based approach. It requires the safety of a system based on the evaluation of possible risks and hazards. It also offers information and guidance on how to use it.

ISO26262: Road Vehicles – Functional Safety aims to provide a unified safety standard for automotive electrical and electronic systems [5]. It based on IEC61508 and applicable for electrical and electric systems installed in cars, lorries, and motorbikes. It provides not only regulations and recommendations in the development of the product from concept to end of life but also points out possible hazards caused by the malfunction of electrical systems. Automotive Safety Integrity Levels (ASILs) is one of the essential components of ISO26262, ASIL determined at the early stage of the development process. It combines the probability of exposure, possible controllability, and the possible severity in order to estimate risks. All these requirements construct an appropriate level of rigor for the vehicle's intended application. It covers two aspects of the system's development: Safety and Intrinsic Quality [33]. This concept complies with the IATF16949, and it will be reported in future research.

Automotive Software Process Improvement and Capability Determination (Automotive SPICE) is developed by the German Association of Automotive Industry. It derived from ISO/ICE 12207, ISO/IEC 15504, and other related standards. In order to assess the software process capability of automotive suppliers, Automotive SPICE provides a common framework by using the process capability attributes and rating scheme. The concept of organizational and process maturity models is introduced into this standard [29].

2.3. SAE J3016, TISAX

SAE J3016 is a technical Guidebook on Cyber Security for Cyber-Physical Vehicle Systems that more focus on taxonomy and definitions for autonomous vehicle-related terms. It aimed to clarify the role of the driver during driving autonomous vehicles, clarify the scope when developing laws, policies, regulations and standards, provide a framework for driving automation specifications and technical requirements, provide clarity and stability in communications in an autonomous vehicle. As figure 1 shows, the six driving automation levels defined in this standard are widely used in the world [34]. This study also provides an overview picture of autonomous vehicle development trends. In this paper, the autonomous vehicle refers to Level 4 and Level 5.

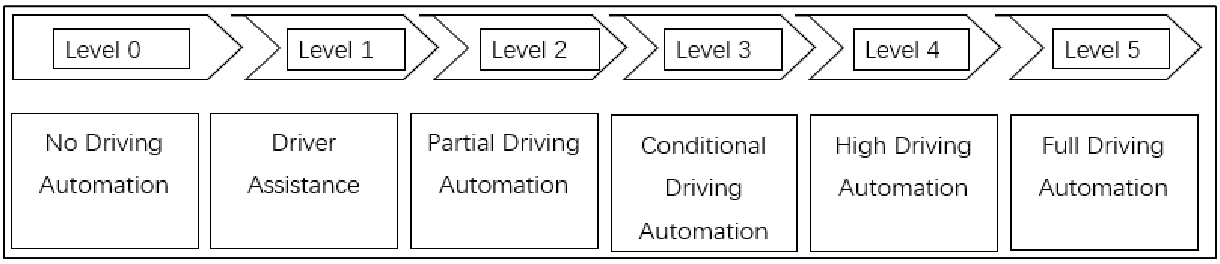

Figure 1. Levels of driving automation [34].

ISO27001 is the standard of the information management system. It establishes a 'state-of-the-art' of how to handle confidential information securely. When two companies exchange confidential data, the standard provides a typical basis. The autonomous vehicles will reach higher levels of connectivity by equipping with Vehicle to Everything(V2X) technology that collects Vehicle to Vehicle(V2V), Vehicle to Infrastructure(V2I) and Vehicle to Pedestrian(V2P) [6]. Obviously, autonomous vehicles equipped are facing more potential attacks; therefore, security is fundamental to V2X technology [6], [7]. Based on ISO 27001, the Trusted Information Security Assessment Exchange (TISAX) is tailored to the specific need of automotive companies. The OEMs and suppliers in the VDA working group improve the vehicle's security by using TISAX. The TISAX assessment for a company can prove the fulfillment of the partner's requirements for handling their information. The assessment includes information security, connection the 3rd parties, prototype protection and data protection [35].

The current QMS is more rely on personal work. They are time and costs consuming because engineers and managers have to handle them manually. They repeatedly work annoying, which might cause mistakes. The process method provides an opportunity to improve the efficiency of implementing QMS as well as the performance of an autonomous vehicle. The process method related to autonomous vehicle development is introduced and reviewed in the next section.

3. Process approach of QMS in autonomous vehicle development

Customer satisfaction is vital to design, implement and maintain the company's quality management system. The terminology of "Process Approach" is essential in ISO9001 and IATF16949, because of that it includes attention to customer-specific requirements and the company's ability to satisfy them. Companies have to deal with numerous linked activities using sources and manage to transform inputs into outputs. These liked activities make up the process. Individual processes construct a system of process over their combination and interactions. The process approach makes the whole quality management system controllable via the linkages between the processes [36]. All QMS include ISO9001, IATF16949, as well as ISO26262, and Automotive SPICE inherits with process approach. Process approach could help improve understanding of process interfaces and interactions, align customer metrics to organization activities, provide common language understood by the industry, improve the efficiency of organizations, tailored the audits through the processes, provide a basis for continual improvement to meet customer objectives. The process transforms inputs into outputs. For the overall picture of quality management systems like ISO9001, the input is customer requirements, and the output is customer satisfaction [31].

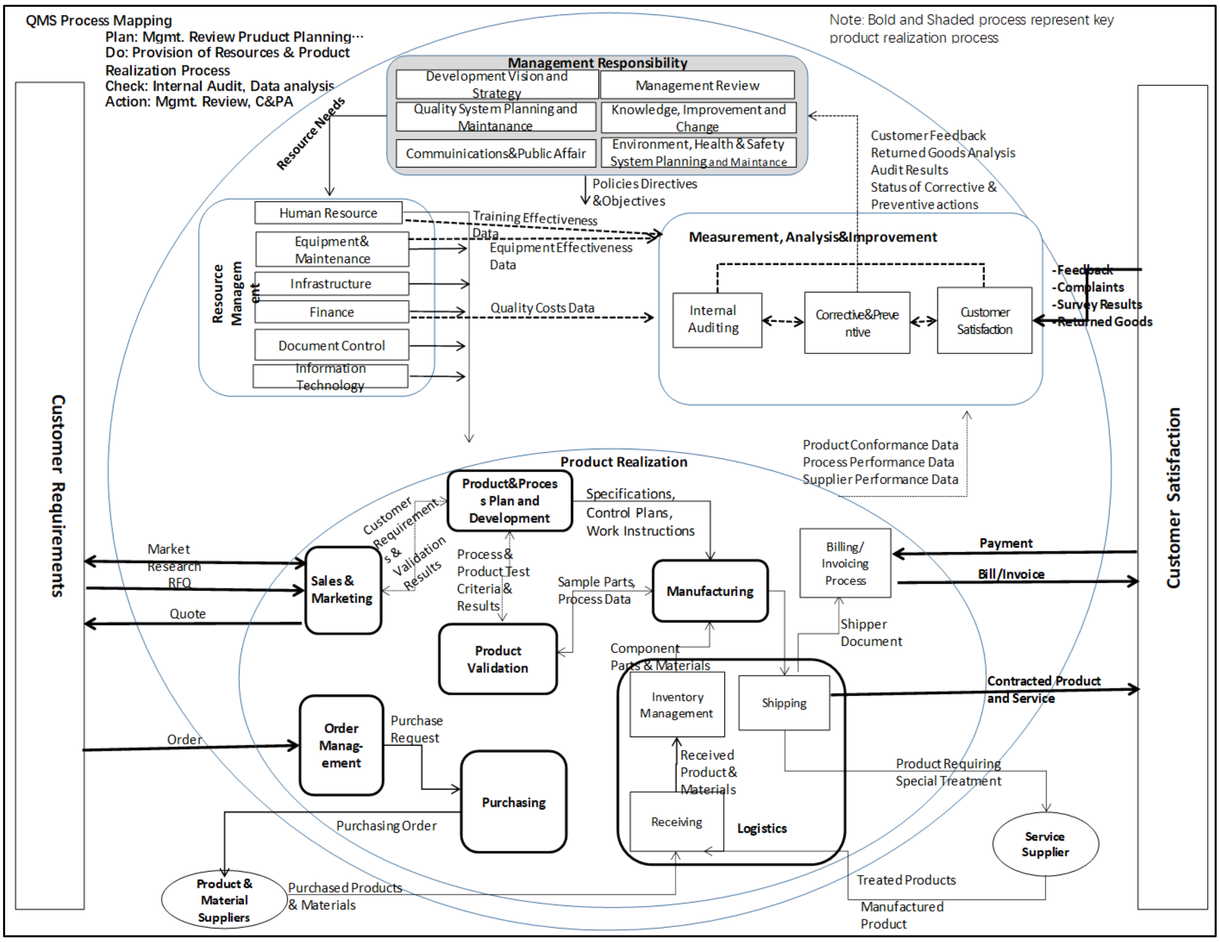

Figure 2. Overview of process mapping of the quality management system in the automotive industry.

An example of process mapping of the quality management system in the automotive industry is shown in figure 2. The solid lines are value-adding activities and the dot lines are information flow in this figure. We can see that it starts with customer requirements, the information and materials via product realization to the destination that customer satisfaction. Management process and supporting process and oriented process make up of the whole quality management system. A customer satisfaction survey delivers information to the management process in order to continuously improve the product. We do not discuss the detail of the whole quality management system but focus on the product development process in this paper. In order to better illustrate the autonomous vehicle development process, the product development and validation processes are picked out and put into an example of a simplified classical process model shown in figure 3. This is a value-added process model that starts from identifying customer requirements and then deliver them to the product development and validation process [36]. The product development process deploys customer requirements and transforms them into the drawings, specifications, characters and parameters of the product. After that, output them to the manufacturing process. The product development and validation process include many sub-processes because the autonomous vehicle is very complicated. It includes project management, quality management, risk assessment, design review, software validation, hardware validation, system validation, road test, and so on. In order to consider the functional safety of autonomous vehicles, The ‘V-Model’ of ISO 26262 is introduced into the product development and validation process [33].

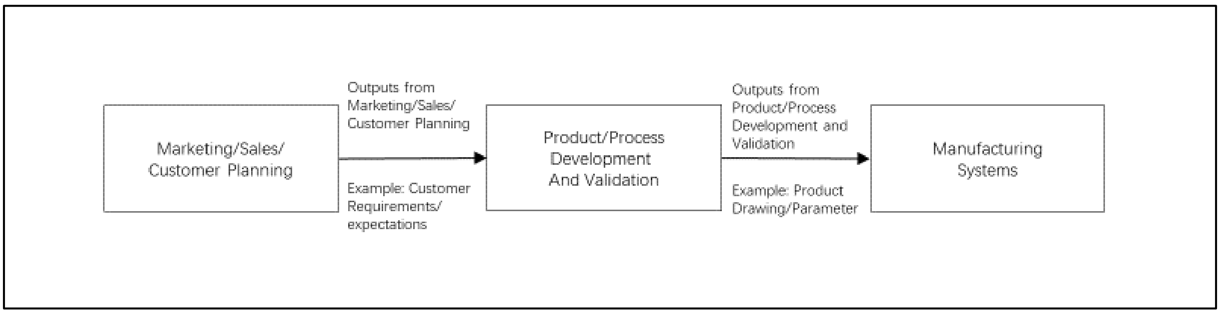

Figure 3. An example of a simplified classical process mode [36].

Although ISO 26262 is not a process, it makes the assumption that a company or organization is already working under a defined development process. This standard applies additional constraints to the processes and focuses on system safety. As figure 4 shows, ISO 26262 organizes its requirements by using the classic ‘V-model’ framework. It looks like a projection from the ‘V-model’ to the product development processes [33]. The Unit Test, Integration Test, and System Test are sequenced to detect the failures as early as possible. Autonomous vehicles validation and verification process also named MiL(Model in the loop), SiL(Software in the Loop) and the HiL(Hardware in the Loop) . Although different vehicle company defines different names for the gate of validation and verification, the hardware and software of the component development should regularly use synchronization.

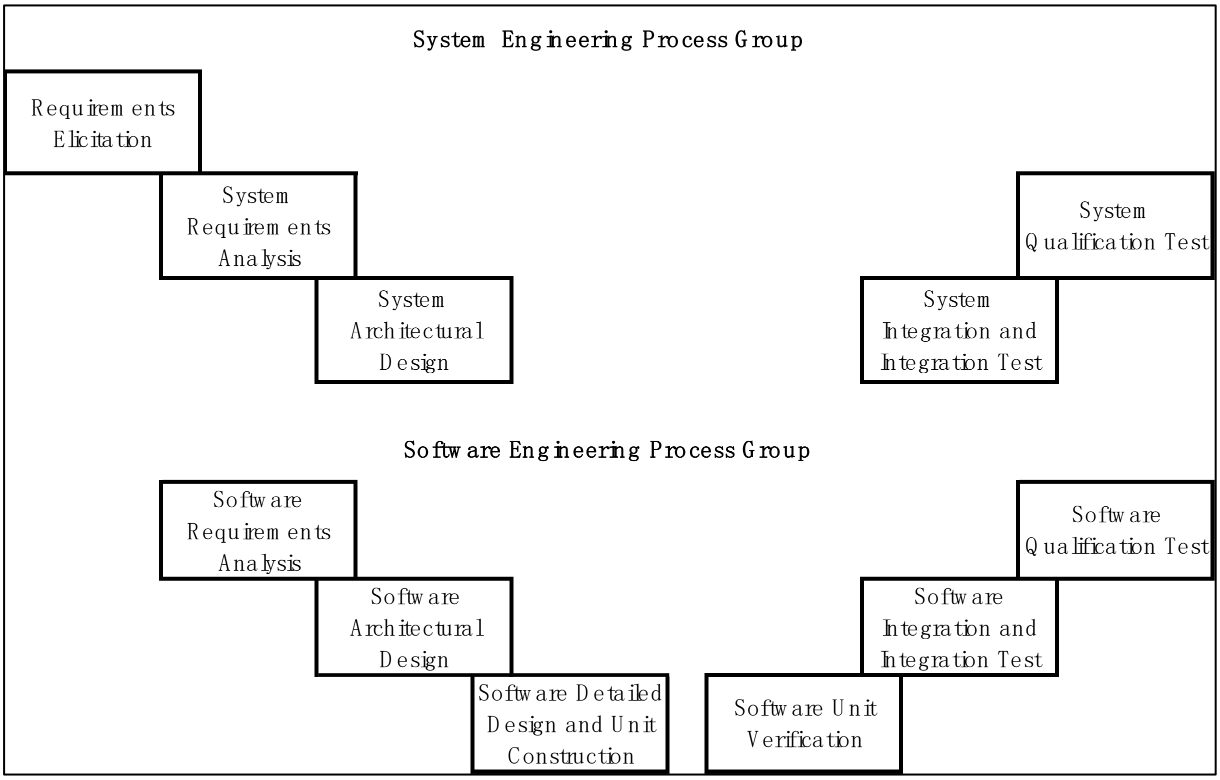

Figure 4. An example of a simplified classical V model [33].

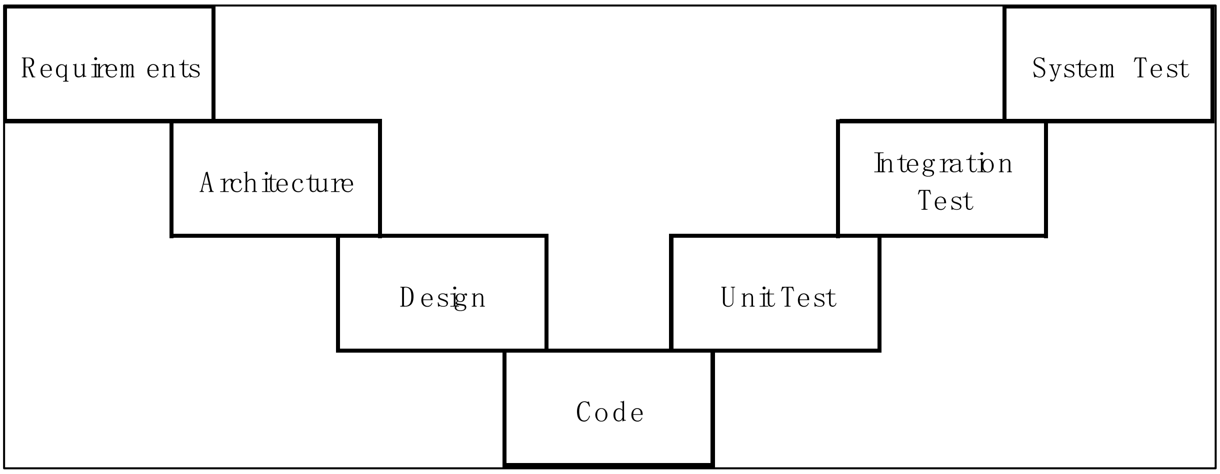

Figure 5. Models of system engineering and software engineering process group [29].

German OEM will require its suppliers to implement Automotive SPICE, which provides a common framework for evaluating the automotive suppliers' software process capability and conformity. The process reference model contains the acquisition process, supply process, system engineering process, software engineering process, supporting the process, management process, process improvement process, reuse process. The process assessment model provides a set of indicators that can also be used for improving the processes. The system engineering process group and software engineering process group are shown in figure 5 [29]. From figure 5, we can see that this model considers software development in software level and system level [29]. Furthermore, the simultaneous between the two levels are also considered. In addition, we can find out that the 'V-Model' of ISO26262 is very similar to Automotive SPICE when we compare figure 4 and figure 5. All include the gate of verification on unit, integration and system verification. Not only because they all come from the IEC standard, but also because of the character of software development.

All these processes mentioned above are possibly integrated into the autonomous vehicle development process. A simplified research process for autonomous vehicle development is provided in the following chapter.

4. The simplified development process for an autonomous vehicle with AI

A framework for the continuous product improvement provided in [8], five steps are contained in this framework. They are knowledge collection, goal setting, usage characterization, system development, and knowledge discovery in usage profiles. This framework provides an efficient way of collecting information, getting data, and then generating knowledge for product improvement.

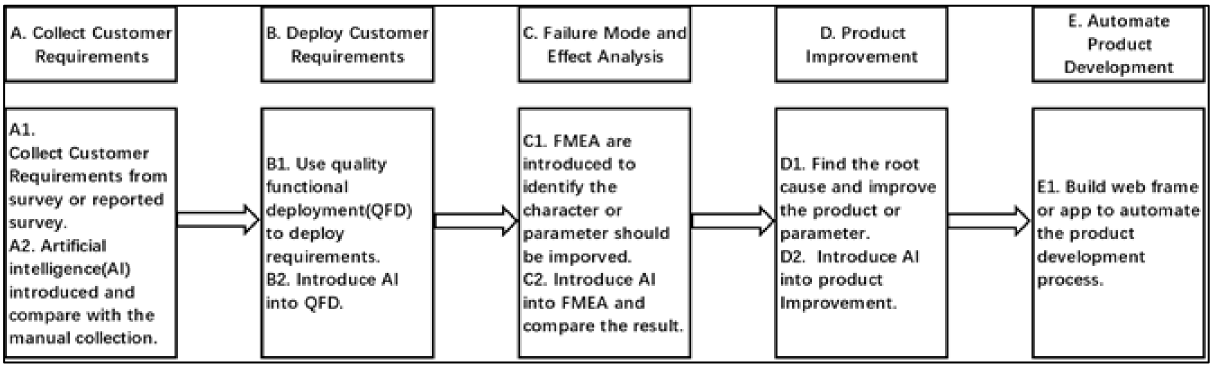

Figure 6. Simplified autonomous vehicle research process.

Obviously, researchers are out of automotive organizations, with limited human resources and test equipment. At the same time, researchers are isolated from the requirements that come from customers. Hereby a suggested process derived, refer to figure 6. This process starts by collecting customer requirements and deploy them. Failure mode and effect analysis are introduced because safety is a critical aspect of an autonomous vehicle. Then turn to knowledge discovery and improve product performance. Finally, build a system to automate the product development process.

In step A, it is collecting customers' attitudes toward the autonomous vehicle as an input to the research. The demands and requirements are various in different nations [9]-[11]. Most of the previous research split the attitude into positive and negative, and then AI technology is possible to analyze the data. For example, semantic analysis with machine learning technique could identify and classify the customer requirements automatically [12]. Then turn to deploy customer requirements. Quality functional deployment (QFD) is widely used in the automotive industry [13]-[15], AI technology makes QFD more capable of decision making [16]. The next step is Failure Mode and Effect Analysis (FMEA). It helps to identify and rank the risks [17]-[19]. When combining with the ISO26262 and Automotive SPICE, it becomes more powerful to reduce the increased risks on autonomous vehicles [17]. On the other hand, the implementation of the Fuzzy Logic technique seen possibles to assist inexperienced users in enhancing the robustness of product design [20]. Step D is focused on the gap found in Step C. AI is well utilized in order to improve product performance [8], [21]. More safety, comfort and convenient autonomous vehicles are relay on the technique in signal processing, machine learning, semantic analysis and other modules in the scope of artificial intelligence [22]-[27]. In consideration of the limited resource, the validation of software just limited in unit level for many researchers, therefore, complete the whole validation process together with vehicle company are more advisable. Finally, build a web service or app to facilitate the whole product development process if it is possible, the database of the web service is a benefit to big data and AI. This is an essential character in Industry 4.0 [28].

5. Conclusion

A process approach is a powerful tool in quality management systems. It helps to make the autonomous vehicles' development process more rigorous. Develop autonomous vehicles in considering priority based on risk and impact on the customer makes the product safer and more reliable. The simplified five-step process could also help synchronize with the car company. Using the same technical language and process performance also benefit from improving the efficiency and reducing costs.

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