Strategic Quality Improvement Management Practice for Domestic Automobile Industry from the Crucial Outsourcing Part Perspective

Fuli Zhou, *Member, IAENG*, Tianfu Chen, Panpan Hai, Panpan Ma, and Saurabh Pratap, *Member, IAENG*

Abstract – **With the rapid development of manufacturing technologies and management practices in the Chinese vehicle industry, quality improvement actions are performed to narrow gaps between domestic automobile and foreign brands. To motivate continuous improvement of domestic automobile products, the quality improvement strategy from the viewpoint of crucial outsourcing parts is proposed in this research. Firstly, quality management activities in the Chinese auto-factory are investigated. Then the strategic quality improvement management practice from key outsourcing parts perspective is proposed and illustrated. This QIP strategy is motivated by infused after-sales information, and detail implementation steps are presented, consisting of quality information infusion, crucial outsourcing parts identification, and preventive decision-making modeling phase. Finally, the industrial application in the Chinese domestic automobile factory shows effectiveness and validity of the proposed improvement strategy.**

Keywords – **Quality management practice, strategic improvement, domestic automobile industry, economics of quality (EoQ), crucial outsourcing parts**

I. Introduction

WITH the rapid development of the vehicle industry all over the world, auto-factories in developing countries like China, India and South Africa show an increasing tendency on vehicle production [1]. The domestic automobile industry in China started late in the second half of 20th century. At the beginning of the 21st century, automobile production had increased significantly, and the annual growth rate kept 2.5%-6.5%. However, the global auto industry had experienced steady growth during 2000-2008. Due to the influence of the global economic crisis in 2008, the global vehicle production volume has decreased to 61.7 million. Till 2010, with the gradual recovery of US and Japan automobile industry, as well as the emerging markets such as China, India and South Africa, the automobile industry had returned to an increasing tendency [2].

Statistically speaking, China had become a country with the most vehicle annual production nation since 2009 and kept an increasing trend. However, it cannot be regarded as a powerful nation with vehicle production due to dramatic quality gaps comparing with those developed brands. The quality management activities implemented in domestic auto factories assist to quality improvement, cost reduction and brand generation [3, 4]. According to the investigation reported by J.D. Power organization, the quality gap of new vehicles between Chinese domestic and foreign brands (like North America, Europe, Japan and South Korea) are showing a decreasing tendency, illustrated in Fig.1 as follows.

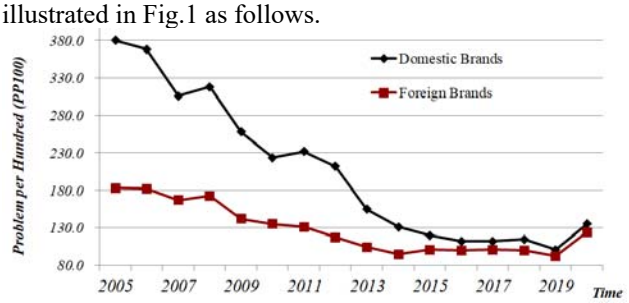

Fig. 1. Quality comparison between domestic and foreign vehicle brands

From Fig. 1, we can see that the quality gap keeps a decreasing trend between domestic and foreign brands in terms of the PP100 (problems per hundred vehicles) index. The data verifies the effectiveness of continuous improvement endeavors conducted by Chinese domestic automobile industry in recent years [5].

Since the procedure of the vehicle production involves complex components, various multi-participation and multi processes, the quality improvement of assembly-vehicle product is usually achieved by local enhancement within a certain process. For instance, a various segmental improvement on material, quality design, machine, manufacturing technique, assembly, and usage pattern etc. all of which will contribute to the vehicle quality improvement [6]. However, most of these quality

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activities are performed from the local perspective towards the quality indicator, while ignoring the economics of quality from total lifecycle scope.

This study tries to perform a quality improvement practice to fill the gap by considering the global EoQ of domestic vehicle products. To stimulate the continuous improvement of domestic automobile product, the quality management practices are investigated based on industrial scenarios in the Chinese auto industry. Different from other quality improvement management practices, this paper addresses the strategic quality improvement from the outsourcing part viewpoint. The main contributions of this study are as follows. Firstly, a novel quality improvement strategy from the viewpoint of outsourcing parts is proposed, and the continuous improvement of automobile products can be achieved by improving the EoQ of crucial procured parts. Secondly, EoQ performance indexes are analyzed, including quality indicators and quality-related cost ingredients. Thirdly, the strategic quality improvement in a Chinese automobile factory is presented to illustrate the proposed quality management practice. It aims at providing a strategic QIP practice to reduce quality defects and improve quality achievement, also trying to set a benchmark for domestic assembly manufacturing plants by this strategic quality improvement management practice.

The rest of this research is structured as follows. Section 2 presents a literature review on quality management activities in the Chinese automobile industry. Subsequently, the quality management practice in Chinese domestic automobile factories is investigated and stated in Section 3. Then, the quality improvement strategy from the viewpoint of outsourcing parts is proposed in Section 4. Finally, we close this paper with conclusions and future study.

II. Literature review

When it occurs to Chinese domestic vehicle products, the most significant characteristic is the relatively cheap price. Compared with automobile products in developed nations, Chinese domestic vehicles have a cost advantage in segmental markets [5]. However, with an increasing consumption capability and an increasingly fierce competition on different automobile brands, domestic auto-factories begin to conduct continuous improvement driven by the “Made in China Strategy” [7]. Besides, the sustainable philosophy motivates industrial factories to focus on the economics of quality within the total lifecycle, instead of the local process, for instance, the procurement and assembly manufacturing stage [8, 9].

The quality management philosophy, theory, methods, and techniques have been widely used to improve the vehicle’s quality and assist in achieving brand reputation enhancement. The quality management system has regulated some standards and principles on practically industrial activities, motivating to the normalized quality operations [10]. The ISO 9000 and ISO 14000 standards systems have regulated the principles for the production site. Besides, the philosophy of total quality management (TQM) and its applications contribute to the construction of standard system [11, 12]. Quality tools and statistical methods (for instance SPC, six sigma, 8D, FMEA, PDCA, and Pareto chart etc.) play a significant role on vehicle product improvement in terms of design, material, equipment, assembly procedure, and human operations [2, 4, 10].

There are many ways to improve the quality of domestic automobiles due to the complex procedure of vehicle production and multiple participants’ involvement. To improve the efficiency of continuous improvement, it is of great significance to performing strategic quality improvements.

III. Quality management practices in the domestic automobile industry

Faced with perplex processes of auto production, the prerequisite of quality improvement strategy development is quality management practice investigation for the domestic vehicle industry. This section presents quality practices in Chinese industrial factories and phased quality activities within its lifecycle of assembly vehicle production. Then, the prevailing continuous quality improvement procedure is highlighted, which have been adopted and implemented by Chinese vehicle plants. In addition, EoQ (economy of quality) characteristics are addressed to provide guidance on specific improvements.

A. Quality generation process

Due to the late start of the domestic automobile industry, Chinese auto-factories mainly focus on four typical processes, including stamping, welding, painting and assembly procedure. Product quality is designed based on customers’ feedbacks and objective marketing research. According to existing manufacturing processes, domestic vehicle product is assembled from parts and components. The vehicle quality generation in domestic automobile factories is as Figure 2 illustrated.

As can be seen from the Fig. 2, the vehicle quality and its performance are dramatically influenced by its part quality and internal assembly operations. The involved quality activities in the whole supply chain of vehicle product may play significant role on quality performance of vehicle products. However, the determination of brand reputation and what auto-factories concern is the perceived quality reflected by vehicle consumers and their intuitive experiences. It is customers’ feedbacks collected from warranty systems that could guide for specific quality improvement. The quality management actions and statistical techniques are employed and adopted to assist the quality improvement of assembly products.

B. Phased quality activities

Since the automobile is one kind of complex assembly products, quality items will occur even there is a little glitch within its warranty period. That maybe requires corresponding quality activities at each stage due to discrepant quality defects. According to the definition of

quality cost (COQ, cost of quality), there are two kinds of quality investment motivating continuous improvement, including prevention and appraisal cost [13]. Prevention costs are associated with quality actions taken to make sure that the production process provides qualified products and services. Appraisal cost items are associated with measuring quality status obtained by the production process. These two kinds of quality activities are usually performed at the stage of part production and assembly manufacturing, both of which are proven to be effective for assembly-product quality improvement [14]. According to the argument of Prof. Juran, quality is produced instead of being tested. From the total lifecycle of vehicle quality generation, quality investments in the former procedure have a greater influence on the product quality compared with the same action in later stages.

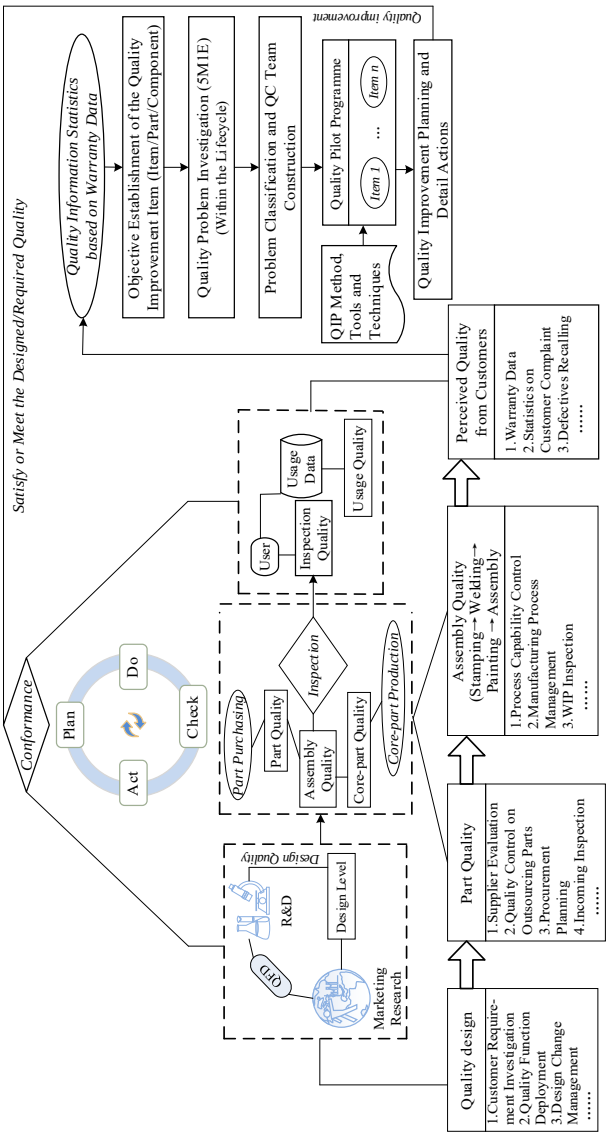

Fig. 2 Domestic vehicle quality generation process

C. Continuous improvement based on EoQ performance

To achieve continuous improvement of the domestic vehicle product, different quality management activities are performed throughout a whole lifecycle. The process of vehicle product updating is also a process of quality improvement. It is the EoQ performance that provides guidance for specific improvement, targeted the high quality with minimum cost as the objective. Quality actions can be implemented within the lifecycle in certain product generation or different generations, illustrated in Figure 3.

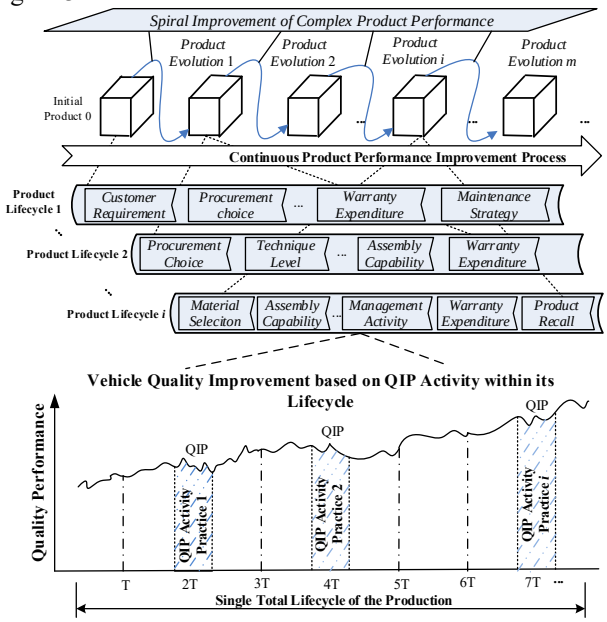

Fig. 3 Continuous improvement practice

As Fig. 3 shows, both two kinds of quality activities (within or beyond the same product generation) could contribute to continuous improvement. It is quality improvement practices assist to realize spiral achievement. After the implementation of quality improvement procedure (QIP) practices, performances of EoQ indicators could be improved dramatically to some extent.

D. EoQ indicators in the vehicle industry

According to characteristics of auto product and the requirement of the industry association, quality items are segmented based on the physical structure of assembly vehicle product (that is "unit –part – component – sub-system – system – assembled vehicle"). The maintenance data and customer complaint information are used to reflect the perceived quality of each objective, represented by R/1000 and TGW/1000 indexes (R/1000: Failure frequency per thousand vehicles; TGW/1000: Things go wrong per thousand vehicles). These two quality indicators are calculated and found in the following Eq. (1) and Eq. (2).

$$R/1000 = \text{Maintenance volume } N/\text{Sample } N_0 \quad (1)$$

$$TGW/1000 = \text{Complaint items } N/\text{Sample } N_0 \quad (2)$$

According to previous publications [2, 3], quality data beyond 3 months after the sale date can be used to reflect the quality of new vehicle product [3]. Therefore, R/1000@3MIS and TGW/1000@3MIS are regarded as quality indicators for guiding quality improvement.

The aim of EoQ requirement in domestic factories is to achieve high product quality together with the economical quality cost. To reflect the economics of automobile products, cost of quality (COQ) is usually adopted and applied in academic researches and industrial organizations [9]. Besides, lifecycle cost (LCC) and total cost of ownership (TCO) concepts are also used to reveal the economics of quality or procurement determination.

For domestic automobile organizations, a novel two-dimensional quality-related cost is proposed to reflect the economics of quality (EOQ) from the viewpoint of the lifecycle and PAF segments [13], which has covered all stages of vehicle quality generation including R&D, procurement, the work-in-process (WIP) storage, key components manufacturing, assembly operation, product delivery and vehicle usage etc. Compared with those visible cost items, hidden costs caused by customers' un-satisfaction are also located within the scope of EoQ philosophy, which have been considered in some quality practices [15]. The novel consideration of invisible cost items assists quality managers pay much attention to the vehicle using experience and the warranty service perception at the after-sales stage, providing guidance for the continuous improvement of next generation.

IV. Strategic quality improvement practice (QIP)

For the Chinese domestic automobile manufacturing industry, almost above 90% components are provided by their outsourcing suppliers [7]. And the quality of outsourcing parts performs a significant influence on the quality of assembling vehicles [16]. In addition, the procurement cost of outsourcing parts had accounted for above 70% of the total manufacturing cost of the assembly vehicle product. Statistically speaking, the quality item of vehicle product is mainly caused by its outsourcing parts. Therefore, the strategic quality improvement management practice from outsourcing part viewpoint is proposed in this research. The aim of this strategy is to improve the EoQ performance of assembly vehicle by using the strategic improvement of crucial outsourcing parts.

A. After-sales information-driven for the QIP

In this rapidly updating era, vehicle consumers not only require basic functions of auto-product but also show higher demands on other attributes like appearance, after-sale service and amazing consumption experience. The purpose of quality improvement is to meet the increasing requirements of vehicle customers under complex and dynamic scenarios. Therefore, quality investments during continuous quality improvement should be customer-oriented. In other words, quality improvement practices would be driven by customer feedbacks from after-sales information or its corresponding warranty system.

There are multiple data sources in terms of customer feedback, including warranty data from the global quality research system (GQRS) and the textual comments from an online forum. Structural maintenance data from the warranty system has proven to be effective for continuous improvement in previous quality management practices [3]. Besides, textual comments of un-structural quality information also could assist auto factories to discover bottlenecks or defects of their products. Data mining practice through machine learning techniques will help the effective utilization of massive comments online, providing guidance on quality actions implementation [17].

B. Strategic improvement from outsourcing parts

The quality improvement strategy from the viewpoint of outsourcing parts highlights procured parts being the improvement objects. There are two stages to perform this QIP strategy, as the following Figure 4 illustrated. Firstly, crucial outsourcing parts showing a greater influence on EoQ of vehicle products need to be identified. And then, specific quality actions need to be conducted to improve the current state of vehicle product. The satisfied EoQ performance of assembly vehicle products will be achieved by specific improvement activities of crucial outsourcing parts.

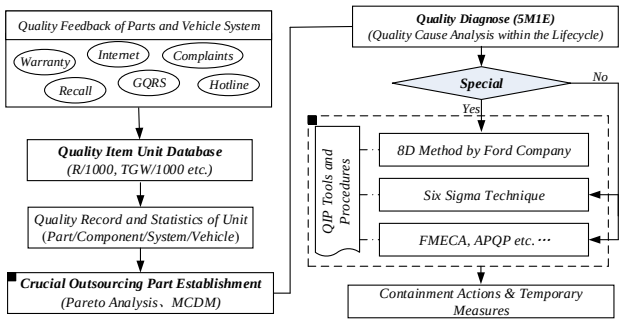

Fig. 4 The procedure of the proposed QIP strategy

(1) Crucial outsourcing parts identification

To implement the proposed QIP strategy, we need to identify crucial outsourcing components that dramatically influence the EoQ performance of vehicle product systems. Therefore, the QIP priority indicator has been proposed to prioritize sequence of auto-parts [3, 5]. Those parts with higher QIP prioritization index will be treated as crucial parts, and will be regarded as main objectives to perform quality improvement activity.

Due to perplex ingredients involvement in continuous quality improvement, this problem can be regarded as a multi-criteria decision-making (MCDM) problem. The MCDM approach, for instance, AHP, ANP, TOPSIS, BP neural network, VIKOR, fuzzy set theory and hybrid decision-making frameworks could be employed to prioritize outsourcing parts [3, 5, 8, 18].

(2) Preventive quality management decision-making

After the establishment of crucial outsourcing parts, quality countermeasures should be performed to improve the economics of quality. Quality improvement procedures, philosophies, tools, methods, and specific actions are addressed in previous publications [2, 4, 10]. However, all these quality management practices are

problem-oriented, which means all these activities are after-the-fact. Even though these practices have proven effective to improve products' quality, the lack of preventive quality practice requires managers to re-look straight into the crucial quality determinations. In other words, quality management decision-making activities in frontier stages need to be re-scrutinized from EoQ perspective of the total lifecycle, such as material, quality design, procurement, and machine tool decision-making issues [19, 20]. The QIP strategy from the viewpoint of outsourcing parts motivates that we need to re-design or re-select the proper parameters or suppliers. It can be performed by the formulated programming model and optimization techniques. The traditional objective function of quality management decision-making is found in the Eq. (3) illustrated, while the novel preventive model considering EoQ becomes the Eq. (4).

$$Optimize\{C, R/1000, R_S\} \tag{3}$$

$$Optimize\{C + OC, R/1000, R_S, TGW/1000\} \tag{4}$$

Where *C* means the quality-related cost (OC is hidden loss or opportunity cost), R/1000 is failure frequency, TGW is customer complaints, and *Rs* is system reliability.

As we can see from Eq. (3) and Eq. (4), the difference between traditional objective and the novel function is the opportunity cost caused by quality defects. The novel quality improvement management practice argues that we should take quality loss into account in advance, which is supposed to be predicted at the beginning stage of product lifecycle. Also, the novel quality improvement practice strategy has regarded the customer complaints as one of the optimization sub-goal, which demonstrates domestic auto manufacturers showing their increasing attention on customers' experience instead of the functional service like before. To perform this strategic quality improvement, various operation programming models will be formulated to turn preventive quality management into reality [7]. Besides, things go wrong (TGW/1000) index reflecting customer complaints is also concerned in the preventive decision-making model. The new multi-objective programming model leads to a systematic EoQ consideration by targeting the total lifecycle cost as the optimization function. Compared with previous quality improvement practices, it is of great significance for quality managers in domestic automobile factories to conduct preventive quality management practices instead of after-the-fact problem-solving.

C. Industrial application of the strategic QIP

The proposed quality improvement strategy has been applied in a Chinese domestic automobile factory (CA Co. Ltd.). In this section, the application situation of strategic QIP management practice is presented. CA auto brand is a famous vehicle assembly organization with vast majority of vehicle products, such as sports utility vehicles (SUV), multi-purpose vehicles (MPV), cars and vans. For this brand, most of the parts are purchased from local auto suppliers, and the automobile plant only focuses on four procedures. According to previous QIP practices, almost above 90% quality defects of the vehicle system are caused by outsourcing parts [7, 17]. Targeting R/1000 and TGW/1000 as crucial EoQ indicators, the roadmap of these two indexes of a certain type of vehicle products is presented in the following Figure 5.

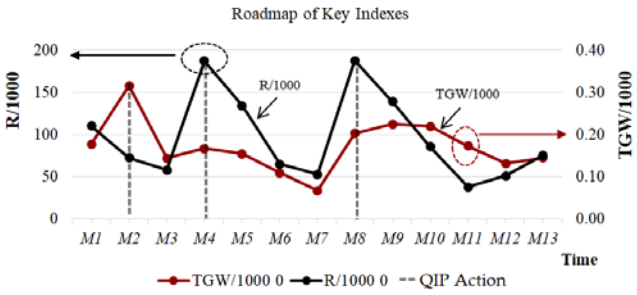

Fig. 5 The roadmap of the EoQ indexes (R/1000 & TGW/1000)

The fused quality information from warranty management system and the global quality research system (GQRS) is scrutinized to assist in discovering quality defects or unsatisfied performance [17]. The MCDM technique is employed to determine crucial outsourcing parts subjecting to multiple conflicting criteria. As Fig. 5 illustrates, there are three QIP actions during the investigated period, which means direct action or preventive quality management are performed towards objective parts.

The successful implementation of fused data utilized in this QIP strategy comes form not only the after-sales quality information, but also the perceived experiences of customers. In other words, the decision-making information covers structured data and un-structured texts, which provides a novel QIP evidence for quality management practice of assembly products. The fluctuation of these two indicators manifests a variety of the quality state. Performances of these two indicators are notably improved (value reduction) after strategic QIP implementations. It is the quality improvement practices implemented in automobile industries that promote domestic auto brand reputation construction. From the historical roadmap of EoQ indexes, we can find the effectiveness of strategic quality improvements.

D. Discussion

With the booming development of global automobile industry, there is an increasing focus on management practices of vehicle aftermarket services, such as warranty and insurance management using data mining techniques [21, 22, 23, 24]. Previous quality improvement management practices are usually performed at certain manufacturing process while ignoring cost spent and specific expenditures after vehicles' delivery and the utilization within their service time-span [17, 25, 26]. Under those circumstances, quality resources would be invested to promote quality status at a certain stage, and a trade-off between quality metrics and cost-effectiveness are optimized to achieve a balance at a single procedure.

Even though quality defects may be occurred in each episode due to the complicated manufacturing process of

domestic automobile products, the outsourcing parts have proven to be most common in auto-factory [3, 7]. In addition, the procurement cost of outsourcing parts accounts for more than 70% of the total manufacturing cost of vehicle assembly product. For these two reasons, the outsourcing parts are regarded as crucial improvement objectives in this study. Different from previous quality improvement practices, the QIP strategy we proposed mainly focuses on the economics of quality from the whole lifecycle viewpoint. And quality improvement techniques and combined optimization method could be adopted in terms of outsourcing parts management process, and this kind of QIP initiatives aim at improving the quality performance of assembly vehicle products. The procedure is designed as figure 4 illustrates, which has been verified by a practical case in a Chinese domestic vehicle assembly plant. From the case presented in figure 5, the EoQ indicator of assembly vehicle has been dramatically improved through quality management countermeasures on outsourcing parts. With the cloud manufacturing technology adoption and artificial intelligence decision-making practice, this quality improvement practice contributes to the quality business innovation. More importantly, this quality improvement management practice has been adopted and applied in other assembly manufacturing sectors. It helps to integrate the quality management philosophy with data mining techniques, contributing to discovering quality defects and strategic improvement. Besides, it has proven to be an effective way to improve vehicle quality and promote a brand reputation. The research viewpoint of this quality improvement management practice considering EoQ of the whole lifecycle facilitates to identify the quality performance of the vehicle supply chain activity.

V. Theoretical implication and managerial insight

This study aims at proposing a novel quality management practice from outsourcing part perspective. It serves both theoretical contributions and practical implications to Chinese domestic automobile industry. This strategic quality improvement management practice provides an alternative way to improve the quality of assembly products by presenting well-ordered steps and detail evidences from a novel perspective. Besides, the fused quality information is collected as the decision-making information to help discover the crucial defects by data mining techniques under the big data industrial scenario.

Theoretically, a novel QIP strategy is proposed by addressing the improvement of outsourcing parts based on the characteristics of domestic automobile manufacturing. Besides, two EOQ indicators, including R/1000@3MIS and TGW/1000@3MIS are formulated and developed to provide guidance on strategic QIP. Finally, the proposed quality improvement strategy from outsourcing part viewpoint is presented and illustrated. And three stages on this QIP strategy implementation are stated, contributing to the development of auto product quality management and flourish of quality improvement management. Regarding as one of the effective quality improvement management practices of domestic automobile industry, it provides a novel way to perform continuous improvement under the background of made-in-China with obvious assembly features. It also provides a benchmark for other assembly-oriented product, such as CNC machine, computer, ship, and other complicated products.

In practice, this study provides an effective QIP strategy for industrial managers to improve vehicle product quality. Different from previous QIP strategies, it focused on the EOQ of the whole lifecycle by providing a novel angle. The product quality improvement and brand reputation promotion can be achieved by this QIP strategy, as well as the maintenance cost reduction. It contributes to lean production achievement of the vehicle supply chain and construction of the strong manufacturing nation. More importantly, this strategic quality improvement practice sets an example benchmark for industrial plants to improve EOQ of assembly products from the whole lifecycle scope. This strategic quality improvement management practice mainly focused on the procurement activity of auto manufacturer, and the similar QIP strategies in other quality-related decision-making problems can also be re-defined and developed throughout the vehicle supply chain process, such as quality design, new product development, assembly procedure and transportation network construction.

VI. Conclusion

Chinese domestic vehicle products are famous for the low-price due to its manufacturing cost. This situation leads to the procurement strategy is always cost-oriented, ignoring other attributes. This phenomenon can be often found in developing nations. Faced with “Made in China 2025”, the characteristic of quality plays an increasing role on manufacturing firms in domestic industry.

To assist quality improvement and brand reputation construction of the Chinese domestic auto brands, the quality improvement strategy from the perspective of outsourcing parts is proposed according to vehicle quality generation process and current state of quality practice in auto industries. The procedures, crucial steps and corresponding techniques are also addressed, as well as the practical applications.

There are some limitations for this study. Driven by the rapid development of the internet of things (IoT) technology and cyber-based intelligent factory, much more precise quality improvement strategies relying on big data techniques and artificial intelligence tools also will be developed to improve the efficiency of continuous improvement. In addition, massive un-structured quality information and after-sales quality activities from consumers’ perspective can be focused to motivate quality management innovation.

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