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Opportunities and Challenges Brought by Digital Quality Management to Big Data Technology

1st Yana Xiao
Science and Technology Service Department
Guangdong Science & Technology Infrastructure Center
Guangzhou, China
xiaoyn@gdcc.com.cn

2st Jiajian Huang
Science and Technology Service Department
Guangdong Science & Technology Infrastructure Center
Guangzhou, China
531776283@qq.com

3st Mengzhen Zhu*
Equipment and Machine Research Department
China Electronic Product Reliability and Environmental Testing Research Institute
Guangzhou, China
zhumzh14@163.com

***Abstract*—As big data technology is widely used in the industrial field, the trend of digital transformation of quality management is becoming obvious. This paper analyzes three major trends in the application of big data technology to the digital quality management, and summarizes the challenges existing in the application of big data in quality management. Three feasible policy recommendations are put forward for the challenges.**

Keywords—quality management, big data, digital technology, quality traceability system

I. INTRODUCTION

Quality management refers to the coordinated activities of directing and controlling the organization in terms of quality. Big data is a new combination of data and information with rapid data dissemination, various basic data types and low relative density of value. Big data includes various technologies, such as data collection, data storage, infrastructure, data processing methods, data analysis, etc. [1]. In quality management, big data refers to the integration of all levels of knowledge about quality and its application in quality inspection, quality decision-making and other processes. Compared with small data, quality management big data has the characteristics of dynamics and randomness. In terms of dynamics, a large amount of data is generated every hour in quality inspection, which can be processed and updated in time by quality big data technology to realize dynamic replacement and ensure the timeliness and accuracy of quality information. Randomness means that the data distribution rule is difficult to find. Big data technology is becoming the key technology affecting quality management. First, a large amount of data such as industrial big data are generated. This has laid the foundation for the application of big data in quality management. Second, the emergence of new fields such as intelligent factories has enriched the application space of big data in quality management. The quality management field will produce intelligent quality management, intelligent process control and adjustment, life cycle product management and intelligent quality management tools. From the specific application cases, taking Honda as an example, Honda uses big data technology and tools to improve product quality. Honda uses the big data analysis software to analyze three data sources, including the car breakdown recorded by the warranty service classification, the technician's record and the call record of the customer service center. By analyzing the quality big data, the company can grasp the rules and find faults in time. This shows that big data analysis can promote managers to make decisions.

Scholars have discussed the application of big data in quality management. Li Yanlin explored the application of industrial Internet in digital transformation of quality, and how big data technology can build corresponding application support capabilities covering supplier quality control, production process quality management, service quality control and product quality traceability [2]. Liu Baosheng thinks that the application of big data in quality management is reflected in the real-time collection, data sharing and analysis of dynamic quality management data [3]. Ding Lei thinks that digital quality management has introduced the tool technologies and methods of cloud technology, edge computing and big data analysis. Based on the principle that all big data analysis can be quantified, the improvement results and status should be tracked [4]. Liu Peng and Guo Jiangjie think that quality problems can be found in time through big data analysis. Quality costs can be reduced [5]. Zong Fuji thinks that the opportunities of big data in quality innovation are embodied in quality control and quality improvement by collecting data, analyzing data and establishing models [6]. On the whole, the current paper focuses on the application scope of big data in digital quality management and the architecture of big data applied to quality management. But the application challenges of big data in quality management are less in these researches. In terms of analyzing the application challenges, Zong Fuji's article is the closest to this paper. Based on his research, this paper analyzes the application challenges of big data in quality management from talents, industrial data and other factors. This paper sorts out three changes brought by big data technology to digital quality management, analyzes three specific application challenges of big data in quality management, and puts forward corresponding solutions according to the challenges.

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II. THE TREND OF DIGITAL QUALITY MANAGEMENT

For the application of quality management level, there have six level (Fig. 1), including final quality control period, process quality control period, quality assurance period, total quality management period, digital quality management period and intelligent quality management period. In the digital quality management period and intelligent quality management period, the big data technology can be essential for the digital quality management. This application can devote a lot of innovation of quality management theory and methods.

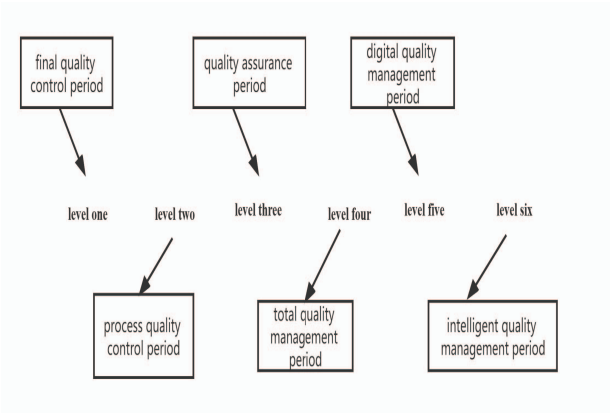

Fig. 1. The development stage of quality theory.

Since the establishment of Quality Control Chart by Dr. Shewhart in the United States, theories and methods of quality management emerged in followed years, such as Deming's PDCA cycle, Joseph Juran Trilogy Program, all of which are put forwarded by experts from the United States, Japan and Europe. Since the beginning of the 21st century, there have been few innovations in the theory and methodological tools of quality management in home and abroad. Digital quality management is the transformation of quality management mode caused by the manufacturing digital transformation. Digital quality management mainly focuses on the transformation of quality management scope, methods and goals. The core of digital quality management is the improvement of digital thinking, digital technology application and other aspects. Overall, the digital transformation of quality management will bring changes in the following three aspects to the quality field.

A. Realization of Quality Traceability System

The quality traceability system is the key application of the transformation from traditional quality management to digital quality management. Internally, the quality traceability system uses an information-based system to record the entire process of products production (Fig. 2), including raw material supply, production, warehousing, wholesale, and retail. The quality traceability system supports the product quality management in all aspects of market and circulation. The existing internet technology feeds information to manufacturer through the quality traceability system [7], which can help enterprises to locate the source of quality problems and take corresponding measures in a timely manner. For the outside of the enterprise, the quality traceability system is conducive to the co-construction of quality at the social level. Multiple entities can participate in quality management through the internet. Enterprises, consumers, and third-party inspection and testing agency will become participants in quality management.

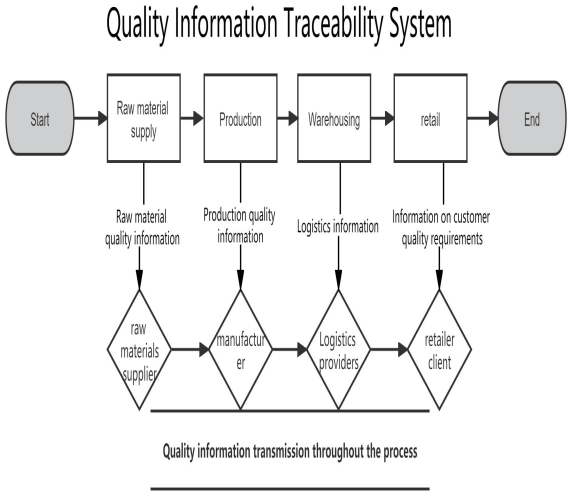

Fig. 2. Quality traceability system.

B. Online Generation of Quality Data

In the early days, researchers can only go to the production line every day or even every hour for measuring data, calculate the mean and standard deviation, and build control charts to monitor the production process. However, in the era of big data, the automatic collection of quality data and real-time data (also called data stream) can be realized by a lot of sensors and the industrial internet. How to propose appropriate methods and tools to monitor the production process with data has gradually become a hotspot issue.

With the application of industrial robots and the application of intelligent sensors in intelligent production lines, the online collection of quality data has effectively improved quality efficiency. For example, Huawei's FusionPlant industrial Internet platform collects data on mobile phone cells, batteries, and boards by real-time monitoring. Combined with the visual inspection model of Hicloud, real-time quality inspection can be realized, and the yield can be improved to 99.6%. Based on Tencent Cloud, CSOT (China Star Optoelectronics Technology) uses deep learning technology and knowledge graph technology to build a panel inspection model and optimize the model using actual production data. The whole process increases the speed of quality defect identification by 10 times, shortens the production cycle by 40%, and reduces manpower by 50%. Once a quality defect occurs, it will be identified by artificial intelligence within 5 seconds. Through digital means, the production data of key processes can enter the system in real time, and the system can calculate in real time and get the quality situation of process level. If unqualified, it can give an alarm in real time, and stop the objects from flowing to downstream processes in time, thus reducing unnecessary

waste. In addition, the timeliness of digitalization is also reflected in the fact that the quality data can be fed back to the superior managers in real time, which directly saves the original statistical cycle. By this way, managers can grasp the quality situation in time and make a quick response to the production situation [8].

C. Predictive Quality Research

Predictive quality research depends on combination of quality information, such as quality data, integration of existing factories data, quality systems information, process data, cost accounting information (Fig. 3). Based on data, predictive quality research can provide decision-making basis for factory production [9].

In addition, with the foundation of large number of Internet-connected devices and the internet of thing in the industrial field, the data collection and analysis can be carried out in a whole system. And the equipment operation information can be fed back to the producer, so as to realize the predictive maintenance of the equipment. The downtime loss and product loss caused by equipment failure can be avoided in time. A lot of quality problems caused by equipment failure can be avoided, too.

Fig. 3. Prediction quality research.

III. Application Opportunities of Big Data in Digital Quality Management

A. Application of Big Data Technology to Quality Traceability Platform

The quality traceability platform provides a lot of application opportunity for big data technology. Big data technology can analyze and process meaningful quality data, and provide accurate predictions for the future business behavior of customer groups.

Various quality platforms based on big data can be applied, such as quality risk early warning platform, quality big data analysis platform, intelligent quality reporting platform. Based on the massive data on the industrial site, the quality big data platform can analyze the key reasons for product yield fluctuations. Take semiconductor technology company's testing process as an example, the testing process contains more than 100 test items, which may produce a data set with one million lines of test records. With a quality big data analysis platform, the traditional report of single indicator can be produced in a quick period. And the platform can generate results that cannot be obtained by traditional analysis.

For enterprises, the big data quality management platform can comprehensively detect the quality problems existing in business data through the built-in detection methods, and can automatically generate data quality detection reports for the information department and business departments to make rectification.

B. Application of Big Data in Quality Prediction and Improvement

Application of big data in digital quality management can achieve positive quality improvement. The traditional quality management is based on the in-process and post-process management in the manufacturing process. Different from the traditional quality management, digital quality management have higher requirement to realize the positive improvement of product quality. The positive quality improvement is mainly divided into the following two parts. On the one hand, quality information about product quality is easy to obtain. Information asymmetry about quality is reduced. The customers put forward higher requirements for quality. On the other hand, by means of big data analysis, customers' diversified quality requirements can be collected and analyzed, so as to realize customers' personalized quality customization requirements. In the case of realizing industrial connectivity, personalized production can be produced for customers. The positive quality of products can be controlled and improved.

In the actual use of products, quality problems will continue to occur. Engineers can use big data technology to collect information about quality problems, and put forward relevant plans for quality improvement based on the information. In this aspect, quality improvement can be achieved.

C. Application of Big Data in Real-time Analysis of Quality Data

One of the most critical processes in the manufacturing process is quality control. In traditional production, the products are usually sampled offline. However, there is a key application of big data technology in real-time analysis of quality data, which make it possible to analyze quality data online. First, based on the development of big data, online automatic detection and control has become a new technology application. High-precision automatic inspection is realized, such as the inspection of printed circuit board (PCB) by automatic optical inspection (AOI).

IV. Challenges of Big Data Application in Digital Quality Management

A. The Problem of Complex Data Structure and Difficult Data Management

Digital quality management have a lot of development in many aspects, but there is still some problem to be solved. It is embodied in the following aspects:

First, there are problems in dealing with data with complex structure. According to Intel's prediction, the total amount of global data will reach 44ZB (1ZB = 1 billion TB=1 trillion GB) in 2020, of which 80% are provided in unstructured form. As the trend of big data is more and more obvious, a large amount of data will be generated in all aspects of enterprises. A large amount of data is produced in product research and development, process design, quality management, production, etc. For example, in the semiconductor industry, the chip will go through many complicated processes such as doping, adding layers, and heat treatment in the production process, and highly automated equipment will simultaneously generate a large number of detection results. Diversified quality feedback and personalized quality demand based on social media have become an important link of quality problem summary and quality improvement in quality management. Different from the traditional quality inspection or collection of quality data from production line, the data of participation from social media has non-structural characteristics. The online quality information together with the traditional quality data forms multi-source and heterogeneous quality big data. Unstructured data means that there is no fixed length and fixed storage. Unstructured data is difficult to analyze. Unstructured data has the characteristics of complex structure. These data include the key information of quality demand, such as customers' perception of value and benefits. Quality management personnel can't ignore these unstructured data.

Second, the format of data collected in each period is different, so the data association analysis cannot be realized. From all kinds of data generated by automated equipment, the data types are different, which leads to poor interactivity, such as image data, video data, document data, interface data, information data, audio data and other data. These data are not interactive and have little connection with each other. How to comprehensively analyze them in a unified analysis framework is a problem.

Third, though the amount of data is huge, there is less effective information. For example, there are a lot of data collected by a large number of sensors, such as photoelectric, thermal, gas-sensitive, force-sensitive, magnetic-sensitive, sound-sensitive, humidity-sensitive, etc. The data collected by different types of industrial sensors has very little content, but its frequency is extremely high, so this feature should be fully considered when analyzing the data. The value density of product life cycle data is different, which brings inconvenience to data processing.

Fourthly, due to the increasing amount of data, the importance of data management has become increasingly prominent, and its security cannot be ignored. For example, data cleaning, data security, consistency check and other problem have become new challenges for the development of digital integration of big data management and quality management.

B. Lack of Comprehensive Tools

The application of big data in digital quality management lacks comprehensive tools.

The current quality tools are based on traditional industrial manufacturing. There are a lot of quality tools with a low degree of automation. These tools rely on a lot of participation and subjective judgment of quality personnel. The current quality tools make it impossible to use real-time sensor data and make a visual description and summary. Digital quality management lacks available tools. The existing tools need to be updated to adapt to the increasingly complex trend of quality data and quality models in the context of quality big data.

The quality analysis tool in the quality field that adapts to the digital quality management can be improved through the following path. Quality tools can be improved by the method from big data technology. For example, the DMAIC method of Six Sigma takes 80% of the data collection time in practical applications, which is inefficient. It can be improved by learning from the rapid data collection technology in the current data analysis field. The tools of digital quality management have a wide range of updates. Specifically, the quality tools used in the fields of data analysis, description, diagnosis, prediction, real-time optimization, and adaptive detection must be updated [6].

C. Insufficient Talents for Comprehensive Analysis of Data Processing and Quality Management

With the application of IT technology in the field of quality management, the area of digital quality management reflects the characteristics of comprehensive. The digital quality management urgently needs to cultivate comprehensive talents with knowledge of data analysis and quality management.

At present time, quality talents cannot match the demand for digital quality management. Quality engineers have the knowledge of quality management on industrial sites, but lack the knowledge of big data, and cannot build models for big data analysis. Quality managers are unable to handle with massive quality big data. Enterprises' quality information can’t be utilized and the digital quality management will be in low-level fields. While big data analysts have comprehensive experience in processing complex data, but they lack tacit knowledge such as quality management and industrial experience. They can only build models through data. The conclusions obtained by data analyst cannot be compared with the quality status quo. Data analyst can’t contact the result of data report with industrial entities, which makes it impossible for further factor analysis. Based on this status quo, in order to realize the digital quality management and correctly play the value of big data analysis in quality management, it is necessary to cultivate talents with both big data processing experience and industrial quality management experience. Big data also puts forward higher requirements for QA (Quality Assurance). Intelligent factories will require higher skills labors, not only to manage equipment and deal with emergencies, but also to analyze and process data[10].

V. SUGGESTIONS OF BIG DATA APPLICATION IN DIGITAL QUALITY MANAGEMENT

A. Strengthen the Collection of Production Quality Data, and Innovate Quality Tools to Promote Positive Quality Design

We should develop quality big data analysis tools. This tool can realize the whole life cycle quality control. This tool can realize the quality feedback of the whole production process. And quality improvement tools should be invented. This tool can analyze the direction of quality improvement according to market demand. Big data analysis tools can integrate design quality data, after-sales maintenance and other data. We should pay attention to research and development of data mining tools, provide the basis for product quality improvement [11]. Quality tools need to be combined with technologies such as big data. The research and development of quality tools needs to expand the traditional statistical methods. Tool innovation will provide a powerful tool for quality improvement [11]. We should pay attention to the collection of production quality data. We need to classify data sets, establish data processing models, simplify data processing models, and extract effective information from a large number of jumbled industrial data. Big data technology should be used to realize quality monitoring and early warning, find abnormal quality information as soon as possible, and reduce the company's quality loss [12].

We should make good use of big data technology. Through big data technology, third-party certification bodies collect all aspects of information about enterprises (such as the industry trend of established enterprises, process parameters of products, results of various testing reports, information and situation of suppliers, etc.), and analyze these data in depth, and summarize the service contents and methods urgently needed by enterprises, so as to improve the service quality of certification bodies.

B. Accumulate Industrial Knowledge and Shift from Traditional Manual Analysis Mode to Model and Big Data Analysis

In terms of process flow, production line quality data should be analyzed to establish the relationship between key production line parameters and product quality. The factory can also improve the relevant parameters of the production line according to the results of big data analysis.

In terms of equipment management, we study the running status of production line equipment according to big data technology. Improve the utilization rate of equipment by analyzing big data information such as equipment running status, product quality characteristics and production technology. The above measures will maximize the utilization rate of equipment, reduce energy consumption, and realize the maximum utilization of manufacturing process resources.

Company quality management should be changed from traditional manual analysis mode to big data model analysis. The company's quality management department should establish a big data analysis framework as soon as possible, which can be used to analyze all kinds of explicit problem (such as quality defects, processing failures, equipment failures, etc.) and implicit problems (such as equipment performance degradation, parts wear, system operation risk increase, etc.).

C. Cultivating Comprehensive Analysis Talents with Data Processing and Quality Management

Reduce the proportion of basic quality personnel and increase the proportion of compound quality management personnel. Under the background of the decrease of general quality record personnel, the company should increase the quality analysts with compound background, and cultivate professionals with both IT ability and industrial engineering. Through talent training, the company can meet the challenge of the application of big data in quality management.

Absorb the excellent experience of domestic and foreign enterprises in the application of big data. The industry should establish an industrial big data platform to promote the circulation and sharing of industry data. The industry needs to set up talent associations, organize special training courses on talent training, and promote the exchange of experience in the application of quality big data in the industry. Broaden the access channels for quality majors to relevant knowledge, offer relevant elective courses, and provide targeted guidance for students' elective courses. Pay attention to the cultivation of professional ability of quality majors, and strengthen practice and employment guidance. Increase the setting of information technology and tool software courses in quality majors, so that students can learn to use relevant quality tools to solve practical problems. Courses of software tools such as ERP system, Python and SAS are offered to cultivate students' ability to explain the analysis results of application scenarios.

VI. CONCLUSION

Digital quality management is the inevitable trend of current quality management development. Big data can be effectively used under the trend of digital quality management. Big data technology can achieve good application in quality improvement, online quality analysis, quality traceability and so on. However, there are still some problems in big data application in digital quality management. Problems such as heterogeneous data sources, difficulties in data management, insufficient combination of data analysis and industrial knowledge, and shortage of comprehensive analysis talents are common. These problems restrict the application of big data technology in digital quality management. Current academia and industry must correctly understand these challenges and take reasonable measures to avoid such problems. Big data technology can be used to improve the current quality analysis tools. Comprehensive talents can be cultivated. They can not only skillfully use digital technology, but also understand the basic knowledge of industrial quality. At the same time, a large number of analysis models will be created, such as industrial quality improvement model, big data quality analysis model, etc.

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