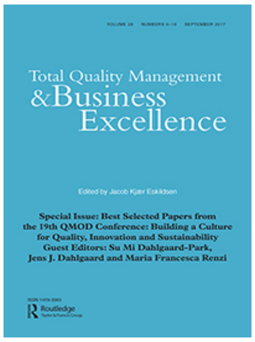

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Building a new culture for quality management in the era of the Fourth Industrial Revolution

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Building a new culture for quality management in the era of the Fourth Industrial Revolution

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The Fourth Industrial Revolution is coming, and it is changing almost all aspects of human life, including the culture of quality and quality management (QM) in industry. This paper first examines the essence of the Fourth Industrial Revolution and its impact on our lives. Next, new concepts of quality as well as QM are discussed as follows. First, we analyse the multiway flow of QM in the stages of plan – design – production – marketing – sales, and data-oriented multiway interactions for creating new value and quality are discussed. Second, four distinctive approaches are introduced for implementing the multiway flow in real-world applications. The four approaches, which utilise Big Data, Artificial Intelligence (AI), Internet of Things (IoT), and more, are composite dimension, team creativity, total inspection, and new valuation. Finally, we argue for the necessity of combining quality experts with data scientists to prepare well for the coming Fourth Industrial Revolution.

Keywords: Fourth Industrial Revolution; quality; quality management; Big Data; Internet of Things; artificial intelligence; data scientist; quality expert

1. The Fourth Industrial Revolution and its impact

1.1. *What is the Fourth Industrial Revolution?*

The Fourth Industrial Revolution was the central theme of the 2016 World Economic Forum (often called the Davos Forum) held on January 20∼23, 2016, in Davos, Switzerland. Professor Klaus Schwab (2015) introduced the theme in his essay noting that 'We stand on the brink of a technological revolution that will fundamentally alter the way we live, work and relate to one another'. Schwab (2016) has also explained the historic context and trends of the revolution. We now live in a world in which billions of people can be connected to each other through mobile devices with unlimited access to knowledge with the help of emerging technologies such as Artificial Intelligence (AI), Big Data, robotics, Internet of Things (IoT), autonomous vehicles, 3-D printing, biotechnology, quantum computing, and more.

The First Industrial Revolution, which began in England in the late eighteenth century, introduced steam-powered and mechanised production. The Second, which began in the USA in the early twentieth century, introduced electric power and mass-production processes. The Third, which also began in the USA in the middle of the twentieth century, introduced computers and the digitalisation of technology. The Fourth, which began in the early twenty-first century, is characterised by a convergence of physical and cyber

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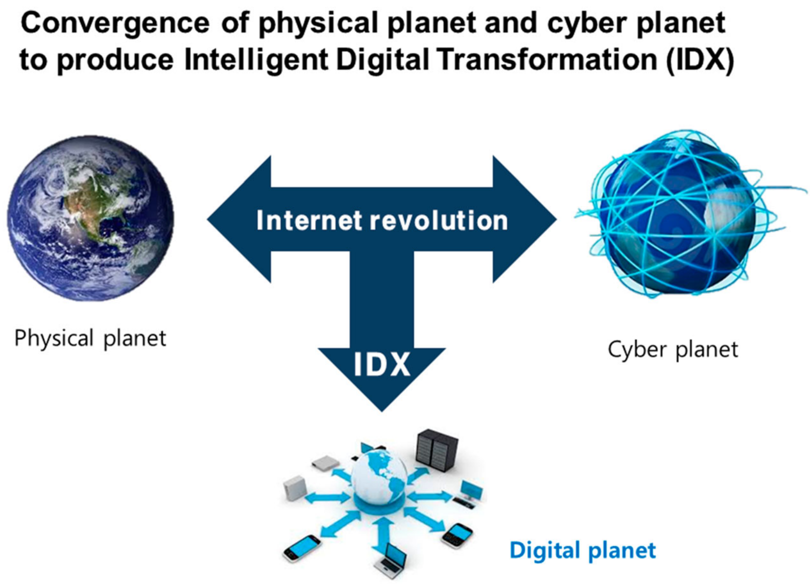

Figure 1. The essence of the Fourth Industrial Revolution.

technologies to produce Intelligent Digital Transformation (IDX), which is shown in Figure 1.

1.2. *What are the major consequences of the Fourth Industrial Revolution?*

The Fourth Industrial Revolution characterised by IDX has a significant impact on people's everyday lives. It will definitely change the future of jobs. 'The Future of Jobs' report published at the 2016 Davos Forum mentions that 'new categories of jobs will emerge, partly or wholly displacing others. The skill sets required in both old and new occupations will change in most industries and transform how and where people work'. In this Fourth Industrial Revolution era, we will witness profound shifts across all industries in the areas of design, production, marketing, sales, and delivery systems. This revolution has four major characteristics.

(1) Homo sapiens evolve into 'phono sapiens' with smart phones dominating most areas of business activities in industry.
(2) Knowledge creation can be possible by the collection, classification, and analysis of large data sets, the so-called Big Data.
(3) AI software begins to compete with human intelligence, with AI robots replacing many routine human jobs.
(4) Mass customisation and personalised production will be realised.

'Phono sapiens' is another name for those human beings who cannot live without their smartphones. This phrase was first coined by *The Economist (2015)*, which noted that 'smartphones have penetrated every aspect of daily life, and 80% of the adult population will own a smartphone by 2020'. There is no doubt that smartphones will influence industrial activities such as design, marketing, and sales.

Many countries are preparing and implementing national strategies for industry to meet this revolution. Germany, for example, initiated 'Industry 4.0', a plan to promote automation and data exchange in manufacturing technologies including cyber-physical systems, IoT, and cloud computing. The USA adopted the 'National Strategic Plan for Advanced Manufacturing' in order to guide federal programmes and activities in support of advanced manufacturing research and development. China announced 'China Manufacturing 2025' through which the country plans to transform itself from a manufacturer of quantity to one of quality. Korea introduced 'Manufacturing Industry Innovation 3.0' which accelerates convergence in the manufacturing sector and sets the stage for innovation in the industry.

Numerous studies discuss quality and quality management (QM) in the Fourth Industrial Revolution. Sangeeta and Sharma (2016) discuss quality issues with Big Data analytical results and its software. Foidl and Felderer (2016) explore research challenges of Industry 4.0 for providing promising opportunities for QM. Brettel et al. (2014) mention the interaction between humans and machines via cyber-physical systems and mass customisation. Kim et al. (2016) note the challenge of maximising the quality of information collected to meet the real-time decision needs of IoT applications. Tuertmann (2016) also discussed the increasing amount of information being collected and that the data-driven design of an intelligent failure management is inevitable, due to connected machinery and new sources of customers' complaints.

2. A new culture for quality and QM

2.1. *A new concept of quality*

Regarding quality and QM, we pose the following questions. What will be the future meaning of quality and what might be the new culture of QM in the Fourth Industrial Revolution? A good reference for this question is the 'Future of Quality Report: Quality Throughout' published by ASQ (The American Society for Quality). This report is a collection of essays offering insights into leadership, the Internet, global aerospace, manufacturing, cities, healthcare, education, energy, customer experience, and quality. Regarding quality, Snee and Hoerl (2015) mention that a statistical engineering approach is best designed to handle large, complex, and unstructured problems. Kano (2015) insists that a new concept of quality for sales will be necessary in the highly competitive environment emerging in the global market.

There is no doubt that the concept of quality will broaden in the Fourth Industrial Revolution to include personalised service quality, as mass customisation and personalised production have become possible. Instead of product quality, more emphasis will be given to design, safety, and service quality. In particular, design quality will become more important than manufacturing quality, since the design influences customers' happiness and there will be no difference in manufacturing quality, because of intelligent manufacturing, robotisation, and 3D printing.

As human beings become phono sapiens, the speed of everything will become an increasingly important factor in quality. The speed of design, production, and delivery is the most important quality for customers in this mass customisation society. After identifying customers' demand, speedy production is perhaps the most important factor for a company to satisfy customers and survive. Such speed is the most important quality value in the Fourth Industrial Revolution.

Quality of connectivity and software will be more focused, since, through IoT, everything is connected through sensors and software. The quality of connectivity and software plays important roles in the smart factory and smart city connected by sensor data. The quality of data will be more critical, since many technologies such as Big Data, AI, and IoT are all based on data and data analysis.

Eventually, service quality and brand quality with speedy management connected to culture and personal satisfaction will have the highest value, as shown in Figure 2.

The new concept of quality will affect not only the scope of its coverage, but also the goals of quality initiatives. The industrial revolution has resulted in strategic changes in both productivity and quality. Figure 3 shows how the eras of industrial revolution have advanced key achievements in human benefits, production strategy, quality goals, and quality strategies. As industrial revolution progresses, human beings have incrementally improved their physical, intellectual, and instinctual abilities. During the Second Industrial Revolution, for instance, we enjoyed automation through which massive production became feasible to meet the drastically increasing demand of commodity products. The computer technology of the Third Industrial Revolution has radically innovated the areas of memory, computation, and knowledge sharing, while the Fourth Industrial Revolution is now anticipating people's behavioural psychology and providing speedy responses for mass customisation.

Quality goals have also evolved according to the revolution stages of industrialisation. We observe a series of strategic quality goals that progress according to QC (Quality Control), QA (Quality Assurance), QM, and finally QR (Quality Responsibility). With innovative technology for connectivity and smart computation, the ability to trace quality and safety is being maximised in all product and service characteristics. The brand quality and the service quality of this stage of the industrial revolution should focus on clarifying the responsibility (or accountability) of quality. Such a goal can be attained through an 'open quality' system in which key factors such as speed, creativity, data analytics, and AI are combined to provide a comprehensive approach for meeting dynamic consumer requirements. We propose using the terminology 'Open Quality' as a new quality strategy in which all quality characteristics of any product and service are designed, produced, marketed, and sold on the basis of open and transparent approaches. The Industry 4.0 may not attain perfect products and services,

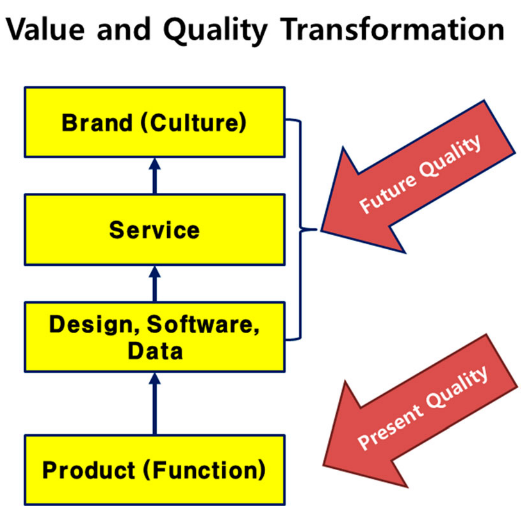

Figure 2. Change in value and quality.

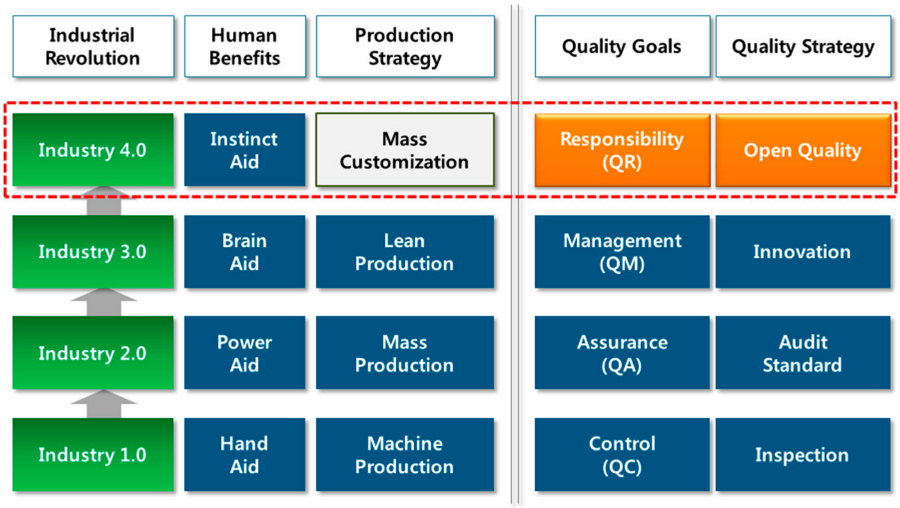

Figure 3. Industrial revolution, quality goals, and quality strategy.

but it should serve as an opportunity to strive for near-perfect responses to customer expectations.

2.2. *A new concept of QM*

2.2.1. *Multiway flow of QM*

Open Quality, a new term first used in this paper, encompasses diverse tools and approaches in attaining excellence in quality. The comprehensive system will become increasingly feasible due to the ever-evolving and agile platform of Big Data, AI, and IoT in addition to mechanical and technological innovation. Though the open quality concept might be viewed in various ways, here we employ the concept for proposing a multiway flow system in planning, design, production, marketing, and sales.

The data and software-oriented revolution changes the QM flow, as shown in Figures 4 and 5. Figure 4 presents the typical existing production system in which feedback occurs after the sale. Hence, it is only a one-way QM, and it takes some time to change QM policy. There are no interactions among the five stages (plan, design, production, marketing, and sales). However, in the era of the Fourth Industrial Revolution, the multiway flow of QM shown in Figure 5 becomes possible by data-oriented multiway interactions across the five stages. Diagnosis and feedback in each stage of the production system will simultaneously be possible with the help of Big Data, AI, IoT, etc. Hence, quality diagnosis and customer demand in each stage will be realised. Additionally, customers' opinion and demand will be instantly reflected in each stage. A data-oriented software system will play an important role in the whole production system. A good example of a production system with multiway flow is Zara (2016), a well-known brand of the Inditex group, the world's largest apparel retailer. Zara's products are based on immediate consumer trends. Its highly responsive supply chain ships new products to stores twice a week. Reportedly, Zara needs just one week to develop a new product and get it to stores, compared to the six-month industry average, and launches approximately 12,000 new designs each year. New items are inspected, sorted, tagged, and loaded into trucks. In most cases, the clothing

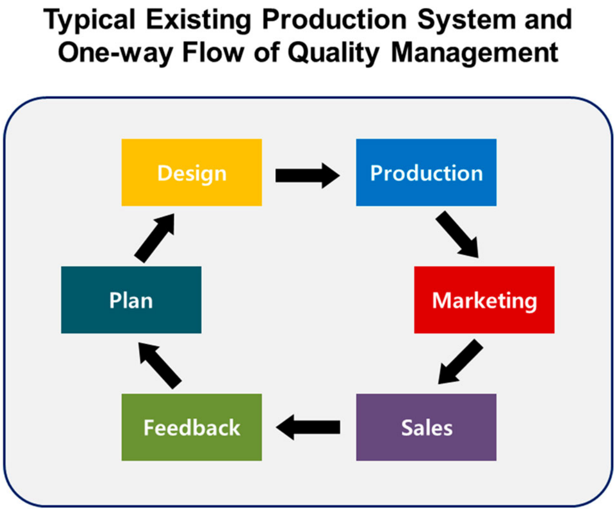

Figure 4. One-way flow of QM.

is delivered within 48 hours. Zara produces over 450 million items per year, and they are multiway controlled in all five stages of the production system shown in Figure 5.

In Figure 5, four distinctive approaches of the Fourth Industrial Revolution are specified near the arcs between the Big Data–AI–IoT platform and the five QM stages. For example, the Plan stage requires isolating and considering 'composite dimensions' for QM of products and services, while the Design stage requires team creativity to cope

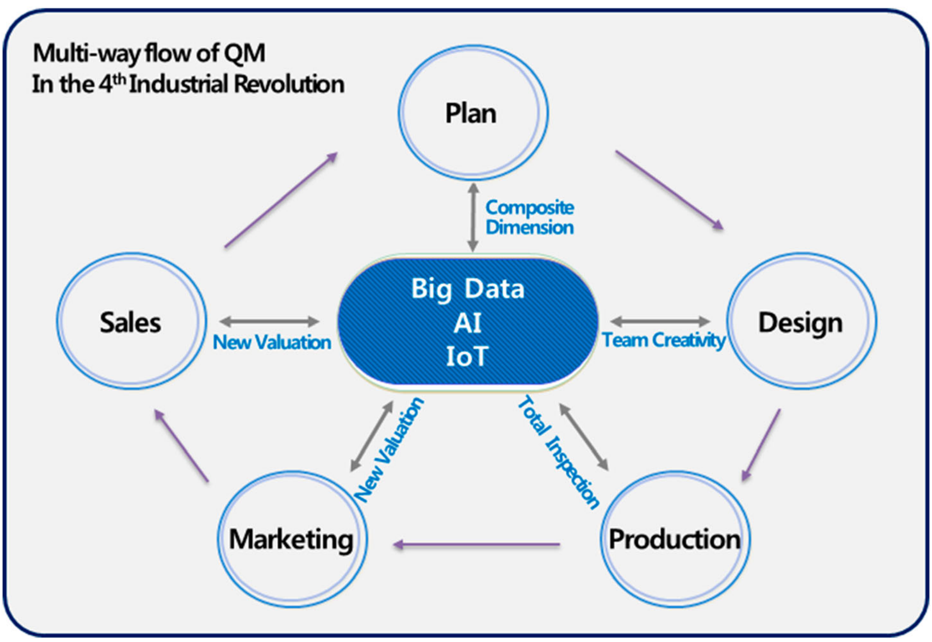

Figure 5. Multiway flow of QM.

with the additional and composite dimensions of the product development process. This does not necessarily mean that each of the four approaches is merely related to a single stage. Although all four approaches may affect the overall QM activities in a collective format, we intend to indicate the highest potential linkage among the four approaches and the five QM stages. The four approaches, which differentiate the multiway flow system from conventional QM, are now further delineated. To emphasise the voice of customers in the market, the four approaches are explained in the sequence of Marketing (Sales), Plan, Design, and Production stages.

2.2.2. *New valuation: creation of new customer value at the stages of marketing and sales*

Big Data is an important part of the Fourth Industrial Revolution. Big Data is a set of data collection (and its analytic technology) which is too big to handle with the existing data base (DB). It provides valuable information to society. Big Data usually includes unstructured data with no format such as social network service (SNS) data, blog data, tag data, news, YouTube, CCTV data, and photos. Based on customer segmentation, Big Data can create new customer value, and provide customised service for customers, which leads to the composite dimension of customer relationship management (CRM). Therefore, new valuation of products and services will become a critical competitive edge for marketing and sales in the Fourth Industrial Revolution.

Intelligent systems will effectively use resources to create new customer value, and the related business will emerge. Sensors will connect everything, and the software that controls the use of resources will provide new business with composite dimensions of QM. Smart buildings and smart cities are good examples. A smart building is a building system that automatically controls the building activities by a sensor-generated diversified data stream that optimises the building conditions on a real-time basis.

2.2.3. *Composite dimension: creating a new dimension of QM in the planning stage*

To provide new value for customers, producers and service providers must create composite dimensions of QM. The composite dimensions need to be visualised in a certain format in order to be considered in the planning stage. Utilising IoT, Big Data, and AI, the ‘smart factory’, introduced by Germany’s ‘Industrie 4.0’, optimises the production process with excellent quality and productivity. Similarly, ‘smart farming’ is also possible with minimum labour and high quality. Speedy management in each stage of the production system, plan–design–production–marketing–sales, becomes possible in the Fourth Industrial Revolution, which will lead to composite dimensions of QM. These composite dimensions must be considered from the beginning stage of product life cycles.

2.2.4. *Team creativity: creative thinking in team activities in the design stage*

The PDCA (Plan, Do, Check, and Act) cycle has been extensively used in QM, as it is a very useful tool. The DMAIC (Define, Measure, Analyse, Improve, and Control) cycle has shown its value in Six Sigma project team activities. The Design Thinking cycle, EDIPT (Empathise, Define, Ideate, Prototype, and Test), first proposed by Rowe (1991), was notably practised by David Kelley, the founder of IDEO. Hasso Plattner, the CEO of SAP, later helped to found the Hasso Plattner Institute of Design at Stanford University in order to promote creative thinking.

Design Thinking has become popular for creative thinking in team activities. Given the prominence of design quality in the Fourth Industrial Revolution, excellent creative thinking will have a greater emphasis in team and QM activities.

2.2.5. *Total inspection: disappearance of sampling inspection at the stage of production*

In the past, sampling inspection has been widely used for statistical QC. However, in the Fourth Industrial Revolution, total inspection will steadily replace sampling inspection with the help of fast information technology (IT) equipped with efficient inspection tools. In the future, automatic identification of defective products and automatic line-stop production system will become more popular.

2.3. *Multiway flow of QM: applicability observation*

We proposed a multiway flow system along with four distinctive approaches for new QM. In this section, we consider the applicability of the four approaches in real-world products and services. To show a direct impact of the four approaches on the fourth evolution of industrialisation, we examine their relations to new functions in the evolving field of automobile technology, namely connectivity vehicles. This area has been often noted as a typical function that will demonstrate the benefits of smart manufacturing and service.

BMW Connected Drive, a connected service of BMW, was available in 36 countries during 2015 (25 countries in 2014). According to Park (2016b), in November 2016, SK Telecom and BMW Korea successfully completed the first trial drive of a connected car using a 5G communication network. For this demonstration, SK Telecom established a 5G test network over a 2.6-km track in cooperation with Erickson, a global communication equipment manufacturer. This network enabled real-time control as data were sent and received at a speed of over 20 gigabytes per second, with a very short communication interval between the base station and terminal of around a millisecond. BMW's connected service has been benchmarked by others as shown in Figure 6 (Kim, 2013).

In the figure, we assigned possible relevances between the connected car and service descriptions and the four distinctive approaches of the Fourth Industrial Revolution. Providing that BMW updates the vehicle sensor data to map information dynamically, we project that the Plan stage may consider composite dimensions such as uncertain barriers and road conditions along the map, the Design stage may be performed in a typical pattern, the Production stage will partially utilise total inspection, and the Market and Sales stages will emphasise the new connectivity in light of recent connected car and service challenges.

Ford is considering a new voice interface system through Bluetooth and USB. The composite dimension, team creativity, and new valuation are highly related to the connectivity project. From our point of view, total inspection seems to be weakly associated with the final quality of the service. Likewise, we attempted to assign some potential relationships for all the matching grids. As shown in Figure 6, all four approaches seem to be strongly related to the future connectivity car and service features of the seven automakers. The four approaches also show strong relationship levels as the functional complexity of the product increases. Through this observation study, we were able to check the applicability of the four approaches and gain confidence in their actual usage.

①Composite dimension, ②Team creativity, ③Total inspection, ④New valuation
◎ High relevance, ○ Normal relevance, △ Low relevance

Maker	Connected Car and Service	Relationship			
		①	②	③	④
BMW	• Updating vehicle sensor data to map information dynamically	◎	○	△	○
Ford	• Voice interface operates connecting over Bluetooth and USB	◎	○	△	○
GM	• Independent connected car-integrating platform	◎	◎	○	△
Hyundai	• Voice recognition technology using Blue Link • Multimedia, navigation, air conditioning, and operation monitoring	◎	◎	◎	◎
Nissan	• Services such as crushing, alarm, location trace on missing cars, health check, responding to emergent situations, etc.	◎	◎	◎	◎
Reno	• Remote control and theft-prevention, emergency rescue communication, remote meter reading, etc.	◎	◎	◎	◎
Toyota	• Advanced driver assistance system (ADAS) including LTE service function and front pedestrian sensing function, etc.	◎	◎	○	◎

Figure 6. Industry 4.0 QM case evaluation.

3. QM of business platform based on customer Big Data

In the society of phono sapiens, customers will respond positively to companies that successfully manage business platform based on customer Big Data. Many global companies such as Amazon, Alibaba, Netflix, Starbucks Coffee, Zara, and Adidas utilise such high-quality business platforms. Platform structure, input data, data analytics, and speedy application of the results are significant components of successfully managing such a platform.

3.1. *Data scientists as quality experts*

Data scientists will lead the Fourth Industrial Revolution with its foundation in software and data-based IDX. Data scientists are experts who can handle DB, find hidden pattern in large data sets, extract useful information through statistical data analysis, and create business opportunities. Therefore, the necessary areas of knowledge for data scientists are as follows:

(1) IT: DB management, programming, Big Data software, etc.
(2) Statistics: Data analysis, statistical analytic methods, statistical packages, etc.
(3) Management: Management science, industrial engineering, management of technology, QM, CRM, etc.

Since the necessary areas of knowledge are very wide, it is not easy for a person to become a data scientist. Recently many universities have introduced data science curriculum to produce data scientists. Song and Zhu (2015) have identified 42 data science programmes in the USA, mainly MS (master of science) programmes. As of 2016, more than 10 universities in Korea offer data science programmes.

Quality experts, trained in statistical QC and industrial engineering, have contributed a lot to QM. In the Fourth Industrial Revolution, quality experts and data scientists will merge into one profession, ‘data & quality scientist’. As shown in Figure 5, they can play important roles in the multiway flow of QM, where data-oriented multiway interactions among the five stages are necessary. Quality and productivity can be improved by diagnosis and feedback in each stage of the production system. The ‘data & quality scientist’ will be well trained for this matter. A company’s black belts or master black belts in Six Sigma management can be good data & quality scientists with some additional training in IT areas, assuming that they have already been trained in statistics and management.

3.2. *Big Data-based AI for QM*

Recently, there has been a trend to adopt Big Data in the manufacturing industry and on production sites. Along with AI, IoT, and Smart Factory, Big Data has played an important role in industrial application as discussed in Wikipedia (2016) and Cho and Chang (2016). In particular, the use of AI based on Big Data is expected to make a significant contribution to the widespread use of QM. AI is a technology that implements human intelligence, such as thinking and learning, through computers. Conceptually, AI can be distinguished as Strong AI and Weak AI. Strong AI refers to AI that has a sense of identity that is capable of thinking freely like a human, while Weak AI refers to AI without the sense of identity. Weak AI will specialise in supplementing human limitation. Examples include AlphaGo, a game program, and Watson, which is used in medical application. AI that can be developed for QM fields is also considered Weak AI.

Big Data can be used to create a high-quality AI product. For example, one can study and anticipate potential malfunctioning or product complaints by utilising AI. Latent causative elements that can deteriorate the performance based on environmental changes can also be identified. As this process can be introduced in the product design and development stage, AI can guide the production of a product that is robust to environmental changes, eco-friendly, and highly reliable. Moreover, AI can collect and analyse various data from the process and discover patterns or sources of variation unobservable in the manufacturing process, even by experts. AI can also be used in the management of new product development. For a firm to be sustainable, it must develop and commercialise a competitive product in a timely manner. However, a firm faces various risks and uncertainty while developing and commercialising its products. Managing these risks is critical for success. As Park (2016b) noted, a firm must identify possible sources of risks and how to respond to them. Various elements of risks can arise during product development, such as evolving customer needs or a change in a development resource or manufacturing capacity. In such cases, the firm must identify a reasonable response as soon as possible. One can use AI to analyse and efficiently manage the risk factors or uncertainty that can arise during the production development period. As such, AI supports the development and production of a high-quality product. AI technology based on Big Data is expected to promote the widespread use of QM.

4. Concluding remarks

In the IDX society of the Fourth Industrial Revolution, the concepts of quality and QM will evolve expanding from product quality to design quality, service quality, and brand quality. The speedy utilisation of a business platform will become an important issue in QM. The Fourth Industrial Revolution is also characterised by software, data, and AI; their quality will constitute the major issues of QM in the future.

In this study, we proposed the concept of QR for quality and the multiway flow system for new QM. Four distinctive approaches, composite dimension, team creativity, total inspection, and new valuation, were also introduced in the implementation process of the multiway flow for real-world applications. We hope that both researchers and practitioners benefit from this study in recognising the future aspects of quality at the start of the Fourth Industrial Revolution.

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Disclosure statement

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