UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

SUSTAINABLE DEVELOPMENT GOALS

SMART QUALITY INFRASTRUCTURE FOR SUSTAINABILITY

SUMMARY

INTRODUCTION

The world has experienced three industrial revolutions with a fourth in progress and a fifth on the horizon. These transformations have brought major shifts to the way we work and live and major changes to the way industry functions. These changes have challenged not only industry, but also the quality infrastructure (QI) to respond and adapt in a manner that will ensure the benefits of the current transformation are realized. The publication explores how quality and quality management (QM) are innovating in response to the challenges of digitalization and Industry 4.0.

INDUSTRIAL TRANSFORMATION IN PERSPECTIVE

This publication briefly reviews the last three industrial revolutions. Each transformation gave birth to many new technologies and inventions, every one of which having propelled us further down the road of industrialization. Some noteworthy inventions that have played a pivotal role in this journey are:

» The invention of the steam engine, allowing steam power to be harnessed for the first time.

» Manufacturing moving to "production based on interchangeable parts".

With these changes came the first monitoring and control activities indicating the emergence of the QI.

During the second and third Industrial revolutions (SIR and TIR) there were major developments in global critical infrastructure with the emergence of key sectors such as electrification, the railroads, the telegraph system and telephone networks. The World Wars (WW) gave rise to modern mass manufacturing and assembly lines. There were tremendous advancements made concerning medicine, chemistry, metallurgy and food production.

In parallel was the evolution of the QI in response to the demands of these transformations.

Metrology saw the introduction of the Metre Convention and adoption of the metric system. Conformity assessment was initially centred on testing and inspection as a reflection of the risks associated with the manufacture of pressure vessels and boilers. It was also being used to manage risk in other areas, for example, ships were inspected for insurance purposes prior to sailing.

After WWII, electrification, telephone networks, automobiles and road infrastructure all experienced exponential growth. Oil and gas industries evolved and grew in importance and were drivers of economic growth. The impact of this surge in economic activity was to elevate the need for the QI to adapt and accommodate the new needs of industry. Standardization was a crucial factor in the development of world transport (i.e. cargo and shipping) and other industries. Conformity assessment (testing, inspection, and certification) was now also becoming widely accepted on assembly lines and in manufacturing plants.

However, by far the most important development of the TIR was the arrival of information technologies including the first computers. A turning point was the introduction of the Programmable Logic Computer which changed the face of manufacturing, allowing for the first time equipment and machinery to be automatically controlled in real time. With this came problems of incompatibility of equipment, software and data. These incompatibilities were preventing industry from maximizing the benefits of the new technologies.

Standardization played a key role in addressing the problems of incompatibility and lack of interoperability. Standards bodies at the international level (such as ISO and IEC) established technical committees composed of international experts to draft international standards that addressed interoperability and incompatibilities around software, data structure and data exchange making interconnectivity more accessible (for example ISO TC 184). Standardization was regarded as a major tool that facilitated the wider dissemination of the new technologies into industry and as a means for opening up new markets.

In the same period, the world saw massive deregulation of the telecommunication sector, and the invention of the World Wide Web. The dissemination of wireless technology with the progression of the mobile sector (mobile phones and tablets) from 1G to 5G was a significant step change resulting in the smart phones we have today, allowing us to connect to the internet and mobile apps.

This use of information and communication technologies changed the world and gave us search engines, social media, electronic commerce, digital media, and the rise of the dominant enterprises of GAFAM (Google, Amazon, Facebook, Apple, and Microsoft). These transformations have created the foundations (the infrastructures, technologies, applications, and services) that are enabling the fourth industrial revolution.

THE EMERGENCE OF THE FOURTH INDUSTRIAL REVOLUTION (4IR)

The 4IR saw an explosion of digitalization and new technologies. Digital production was driven by these advanced digital technologies, including the **Industrial Internet of Things (IIoT), big data and analytics, advanced robotics, artificial intelligence (AI) and machine learning, cloud computing, and additive manufacturing (3D printing)**. Advanced digital technologies brought a radical transformation of industry and specifically manufacturing.

A GROWING SUSTAINABILITY IMPERATIVE

There would be little or no benefits for humanity from the 4IR if we were to destroy the earth in the process. With the advantages that new technology brought to manufacturing, it became evident that an increase in global consumption dramatically increases the use of energy and the earth's natural resources. There was a recognition that the earth cannot sustain this level of production indefinitely unless something changed. The world needed a new model of industrialization and infrastructure development that would sustain the earth for future generations and hence the sustainability imperative was born. The sustainability imperative demands a decoupling of economic growth from the use of energy and the earth's resources. It was obvious that manufacturing has a major role to play in achieving the sustainable imperative, and the 4IR gave industry the opportunity to rethink manufacturing and QI in line with this imperative. The "sustainability community" sees the 4IR as a unique opportunity to establish a circular economy where industry would have to address the entire process of designing, sourcing, producing, delivering, and servicing products in line with the sustainability imperative and circular economy.

SMART QUALITY INFRASTRUCTURE

The advent of "advanced digital technologies" opened new opportunities for QI and its organizations. Likewise, the QI needs of the 4IR are re-defining the notion of "quality". This drives the QI components to perform differently and provide new types of services. This transformation is referred to as "Smart Quality Infrastructure" (Smart QI) or "Quality Infrastructure 4.0."

This publication goes into some detail of how the various components of the Smart QI have adapted to the challenges of 4IR and Industry 4.0. We highlight some of the achievements below.

SMART METROLOGY

A dramatic increase in measurement data and autonomous actions of equipment has given metrology new challenges. Metrology is successfully responding to the demands of automation of tests and measurements and the use of metrological inspection data in real time. It is capable of meeting the demands of measurements conducted in-process online as well as embedded inspection. It also addresses touchless calibration in which the calibration standard remains in the laboratory, remote from the unit under test.

SMART CONFORMITY ASSESSMENT

Conformity assessment deals with the automation of test and inspection activities, remote inspections, and auditing as well as the use of blockchain for certification and traceability. It uses all available technologies (AR/VR, etc.) to do this but also maintains the integrity and trust in the processes.

SMART STANDARDIZATION

It makes full use of all the tools associated with the new technologies including use of IT platforms for standards development and collaborative authoring. International standards organizations are now exploring the concept of Machine-Readable Standards (called SMART Standards) that would allow the technical content of standards to be read directly by a machine (as well as by humans).

SMART ACCREDITATION

Digital transformation is also substantially impacting accreditation, which now explores remote assessments as well as blockchain technologies as a secure mechanism for e-certificates.

SMART QUALITY

The publication would be incomplete if it did not address the impact that digitalization is having on quality not only in the enterprise itself, but also in the supply chain. Enterprises use their supply chains to deliver a quality product/service with many components supplied by external suppliers. The integration of these new technologies is placing significant pressure on Supply Chain Quality Management to not only keep pace with digitization, but also to innovate.

Quality responding to challenges of the new technologies has taken the designation "Smart Quality" (also known as Quality 4.0). "Smart Quality" takes this entire approach to the next level, with the use of advanced robotics and sensors providing real-time monitoring and measurement with instantaneous feedback loops and pre-programmed corrections/corrective actions performed automatically via the Internet of Things (IoT), IIoT and the Internet of Everything (IoE). This is further augmented by machine learning, predictive analytics, and AI to continually improve the "automatic" decision-making processes, supported by blockchain/distributed ledger technology for the purposes of traceability and the provision/tracking of data for continual improvement purposes.

The context of the enterprise is crucial in how it responds to the challenges of Industry 4.0 and digitalization. The publication explores four combinations, ranging from enterprises with a traditional approach to quality and operating with little or no digitalization to those enterprises that operate in the context of "Smart Quality" and within a high digitalization environment. It looks at the implications for the enterprises of each combination. Enterprises that have embraced digitalization will need to rethink their approach to quality.

It also provides a detailed look at the use of "Smart digital tools" applied to typical Quality Management System (QMS) processes for any enterprise. For example, the process of "design and development" of products and services (from ISO 9001) would be supported by social media, VR/AR, AI and machine learning, IoT, IIoT, big data and predictive analytics. The publication identifies the advanced technologies to be used for each of the QMS processes ranging from strategic management to risk management, marketing and customer processes, production and service provision maintenance, monitoring, measurement, and problem-solving.

SMART QUALITY IN THE SUPPLY CHAIN

Digitalization is placing significant pressure on QM to innovate to ensure quality throughout the manufacturing process and the smart value chain. This publication explains the difference between supply chains and value chains and the impact of advanced technologies on both.

Manufacturing has progressed from mass production to mass customization. Scale and volume are no longer key success factors; flexibility and production close to customers are now the success factors with manufacture on demand and little or no inventory. Digitalization, together with smart value chains and sustainable value chains, has facilitated the concept of smart manufacturing or smart factory, which is a broad production concept that optimizes the manufacturing process. It is a technology-driven approach that utilizes internet-connected machinery, modelling, big data, and other automation to monitor the production process and increase manufacturing efficiency.

The smart value chain encompasses digitalization, faster response to customers and improved communication throughout the chain. The sustainable value chain brings in additional issues of social responsibility, good governance, trust and transparency, net zero carbon and circular processes minimizing waste. The smart value chain stakeholders need to review the assignment of quality functions and governance in their structures, and refresh and integrate the QMS across the enterprise to facilitate enhanced quality management processes into the multi-tier supply chain.

The publication details why enterprises need to shift towards embracing the sustainable value chain with all its benefits.

THE ROLE OF THE QUALITY PROFESSIONAL

Lastly, digitalization is significantly changing the role of QM within the organization. QM professionals need to operate in an increasingly complex and fast-moving global context, dealing with new markets, new compliance requirements, and new supply chain challenges. QM professionals will need to adapt to support digital transformation, helping enterprises to design and redesign systems and processes, and to translate big data into real value in terms of preventing failures and solving complex problems. Consequently, the skills needed by QM professionals working in smart value chains are very different from those previously required when QM was an in-house discipline. The publication identifies the skills that quality professionals will need in the future.

FUTURE TRENDS IN THE SMART VALUE CHAIN

Looking to what the future holds is difficult as the speed of change will likely increase more rapidly as technology adapts and changes. We can identify that in the future:

- Product manufacturing and services will converge based on market demand.
- Manufacturers will redefine their process around the new technologies.
- Hybrid human-machine processes will be on the rise.
- Manufacturing will incorporate more automated intelligence.
- Manufacturing culture will embrace digital.

These will likely bring new challenges for all.

CONCLUSION

Digitalization and the 4IR have changed everything about the way we work, live, interact with each other, and spend our work lives and leisure time. Both Smart QI and Smart Quality are integral parts of the 4IR and Industry 4.0 and are vital to their success. However, the sustainability imperative must be taken on board if any of this is to benefit humanity, otherwise nothing will succeed.

We have a unique opportunity before us to leverage all of the knowledge gained through four industrial revolutions in order to take full advantage of the fifth and to ensure its contribution to the three pillars of the sustainable development: the planet, people and their prosperity.


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