Current Research Issues in Quality 4.0

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28 August 2024

What is research ?

- A **logical and systematic search** for new and useful information on a particular topic
- An investigation of **finding solutions** to scientific and social problems through objective and systematic analysis
- **Search for knowledge**, that is, a discovery of hidden truths - knowledge means information about matters
- Most importantly, research leads to **new contributions to the existing knowledge.**

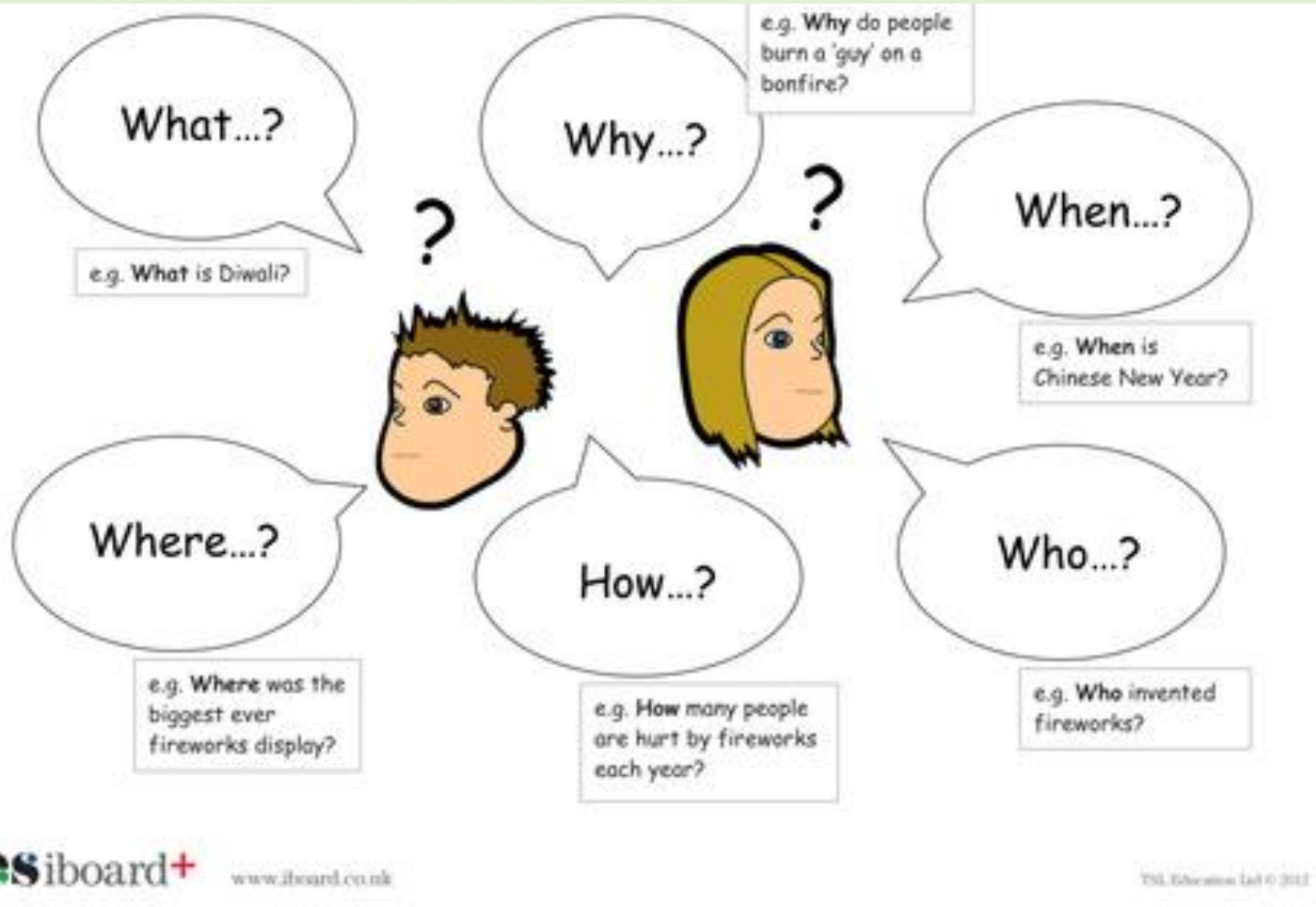
What are motives for doing research?

- To discover new facts
- Verify and test important facts
- Explore or develop new method/technology/system
- Analyze an event or process or phenomenon
- Identify the cause-and-effect relationship
- Develop new scientific tools, concepts and theories
- Solve and understand scientific and nonscientific problems
- Find solutions to scientific, nonscientific and social problems and
- Overcome or solve the problems occurring in our everyday life

What do you think is most difficult type of research question?

What kinds of words you use when writing your research questions ?

Which ones are the most difficult to get answers?



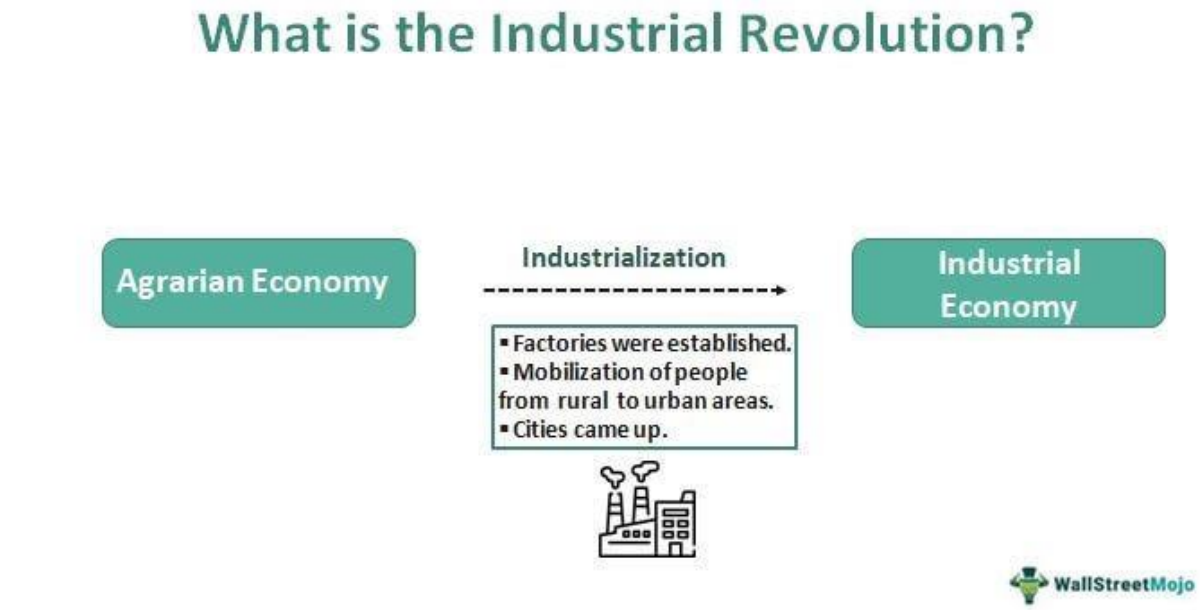
Question word
What (other)
To what degree / extent
Why is / are / do / should
Do / Does
What is the benefit /effect / impact / value of
What economic / effect / factors / forms / future
How are / is
How has / have
How may / might / will
When are / will / would
Has / Have
How feasible / economic / sustainable
What challenges / dangers
What impact does / did
How much of
In what ways does
What causes / determines

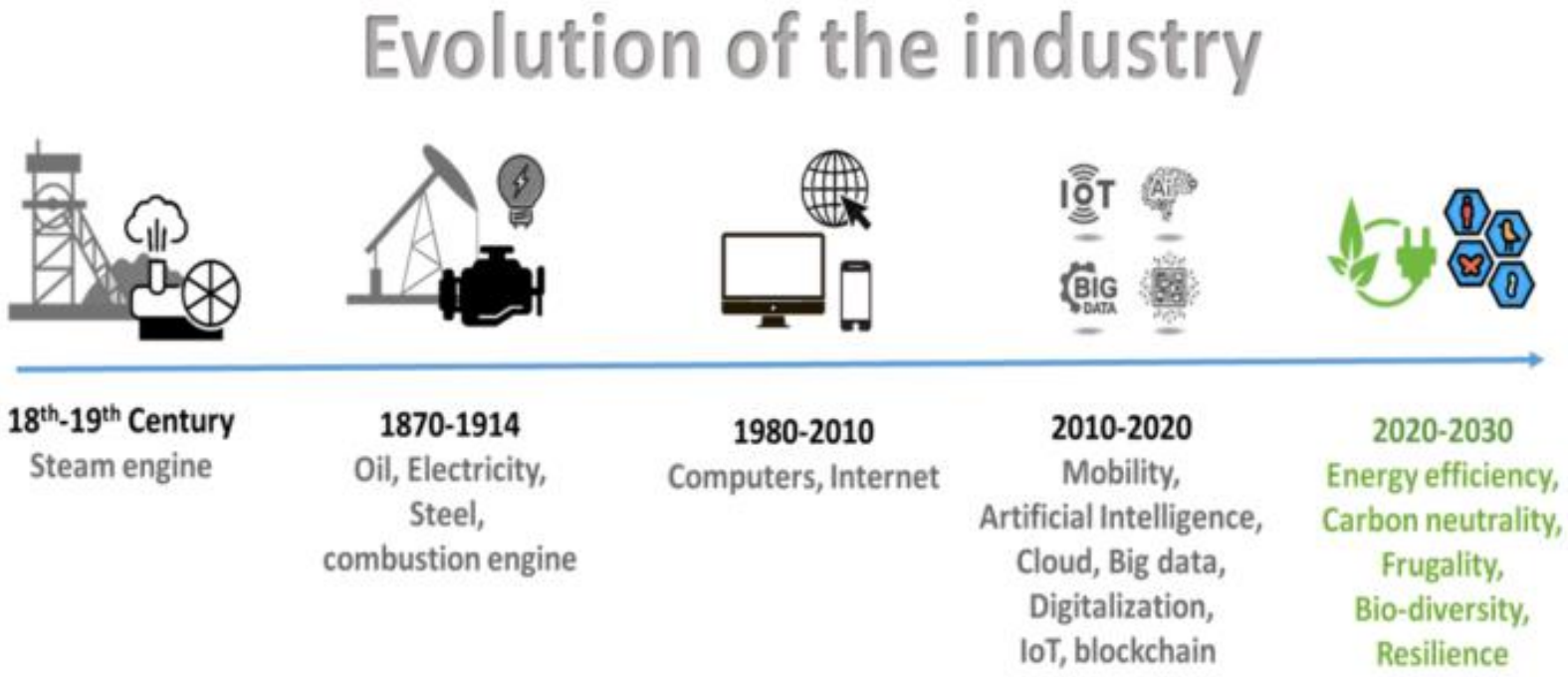
My Sharing Today

- Highlight some current topics in Industry 4.0 and followed by Quality 4.0
- Provide analysis from these research and suggest possible areas (I believe) important in this field and to suit for your own context
- How can Industrial / Quality Engineers stay relevant (higher quality, increased competitiveness, improved productivity, reduced costs, efficient processes in organizations) in VUCA (volatile, uncertain, complex and ambiguous) world we live in today – Post-Covid, Geo-political crisis, Disruptive supply chain, Economic Challenges, Intense Global business competition, etc.

Who is an *Industrial Engineer*?

Industrial Engineer—One who is concerned with the design, installation, and improvement of integrated systems of people, materials, information, equipment, and energy by drawing upon specialized knowledge and skills in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems.





- Industrial Revolution - the process of change from an agrarian and handicraft economy to one dominated by industry and machine manufacturing

Technological changes introduced novel ways of working, living - fundamentally transformed society.

Some interesting **Topics** being published/researched in IR 4.0 recently

- **Industry 4.0 Implementation Cases/Framework**
- **Readiness Level of Industry 4.0**
- Challenges / Difficulties to Industry 4.0
- **Levels achieved in Industry 4.0**
- **Industry 4.0 relationship with TQM**
- **Managers reaction to Industry 4.0**
- **Barriers to Industry 4.0**
- ….. and many others

INDUSTRY 4.0 TECHNOLOGIES

The road towards industry 4.0: a comparative study of the state-of-the-art in the Italian manufacturing industry

Ting Zheng, Marco Ardolino, Andrea Bacchetti and Marco Perona
Rise Laboratory, Department of Mechanical and Industrial Engineering, Universita degli Studi di Brescia, Brescia, Italy

Abstract

Purpose – This paper has two objectives: first, to investigate the state-of-the-art of Industry 4.0 (I4.0) adoption in Italian manufacturing firms and, second, to understand variations in technologies implemented and business functions involved, benefits perceived, and obstacles encountered in I4.0 implementation over a three-year period.

Benefits

- Significant strategic benefits leading to economic and financial performance – flexible, better decision-making
- Costs Reduction
- Quality Improvement
- Time Reduction
- Flexibility Improvement

Findings

Barriers

1. Top management awareness, champion change management
2. New skills and competency in IT Ind 4.0 Technologies, digitalization, Additive Mfg., Robotics, AR, VR, AI
3. Different maturity levels of organizations of enabling technologies – need integration of Technologies used with IT systems
4. Implementation costs especially manufacturing SMEs not having sufficient financial capacity to support investment

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Involvement of Business Functions

- Crucial for Integration and Successful Adoption
- Most involved – R&D, Production, IT
- Lowest involved – HR
- Unbalanced penetration of Ind 4.0 on the Business function
- After 3 years (2020) = quality and logistics more involved
- **(Comment : to be successful and sustainable more business functions need to be involved early in the process)**

Readiness Level

- Poor adoption in Italy - esp. AR, VR, AI -5%
- IIOT and AM = 20%
- Why low adoption?
- Technology adoption is a long-term evolutionary process – need company's Technology Strategy
- Implementing IR 4.0 = **need Technological and Organizational alteration** (adjustments, modifications, changes) – need to retrofit existing production system and equipment
- Firm size is a challenge – SMEs low adoption –costs issue, and skills/competencies

The mark of industry 4.0: how managers respond to key revolutionary changes

Erlinda N. Yunus
Sekolah Tinggi Manajemen PPM, DKI Jakarta, Indonesia

Purpose : to provide a framework of managerial responses to the Industry 4.0 phenomenon, which has impacted the productivity of Indonesian manufacturing companies (Large)

Findings : Indonesian manufacturers have engaged in Industry 4.0 initiatives: cyber-physical systems, the internet of things, Big Data and cloud computing. These initiatives require managers to adopt best practices, appoint champions as change agents, conduct training and even tailor the job qualifications of their subordinates to suit the current technology.

Recommendation : exploratory framework could guide managers in their strategic and operational decisions while embracing the Industry 4.0 transformation inside the organization

Interesting comment by author :- "**human resources as their primary challenge** throughout the Industry 4.0 implementation. Some of their concerns were the limited knowledge of the operators and the resistance to change. The companies had to implement a systematic change management process that consisted of intensive communication, training, campaigns and appointed employees who served as **champions**"

The mark of industry 4.0: how managers respond to key revolutionary changes

Erlinda N. Yunus
Sekolah Tinggi Manajemen PPM, DKI Jakarta, Indonesia

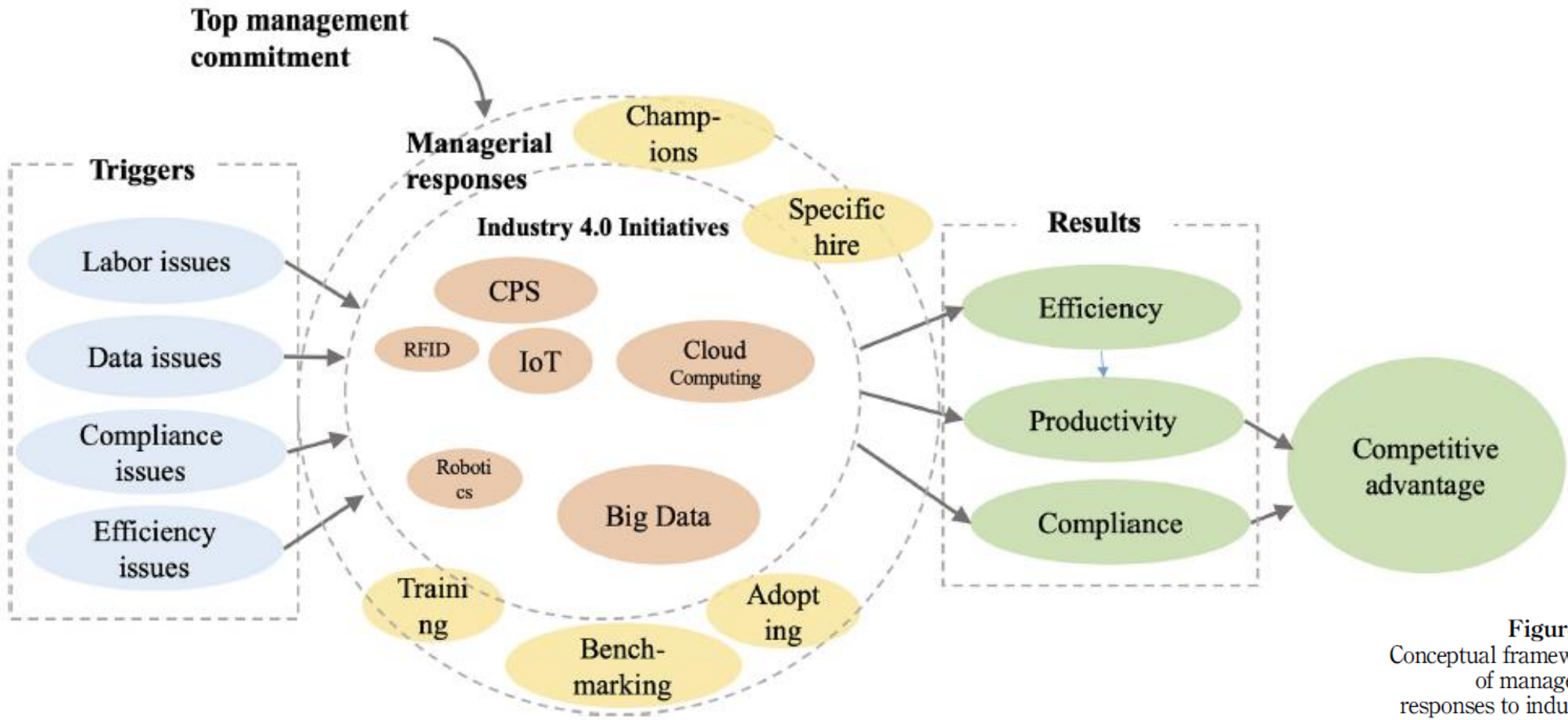

Figure 2.
Conceptual framework of managerial responses to industry 4.0 adoption

International Journal of Productivity and Performance Management ,Vol. 70 No. 5, 2021 pp. 1213-1231, Emerald Publishing Limited 1741-0401 DOI 10.1108/IJPPM-12-2019-0590

Factors influencing Industry 4.0 adoption

Sabai Khin and Daisy Mui Hung Kee
School of Management, Universiti Sains Malaysia, Penang, Malaysia

Findings – Industry 4.0 Adoption

1.Driving Factors

2.Facilitating Factors

3.Impeding Factors

And the Expected Benefits and Opportunities given by the respondent

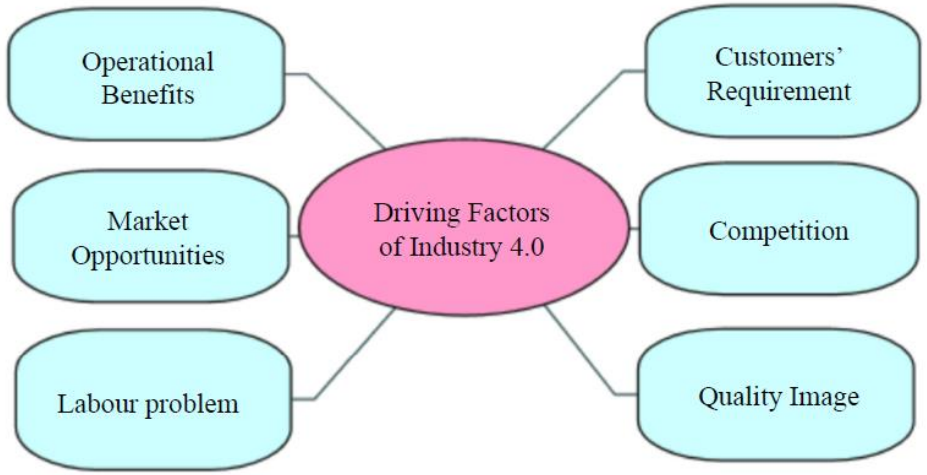

Figure 1.
Driving factors of I4.0 adoption

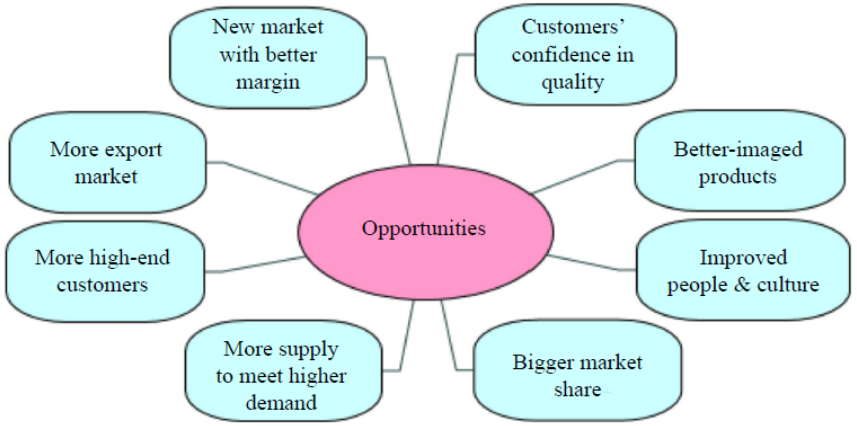

Figure 3.
Expected opportunities of I4.0 adoption

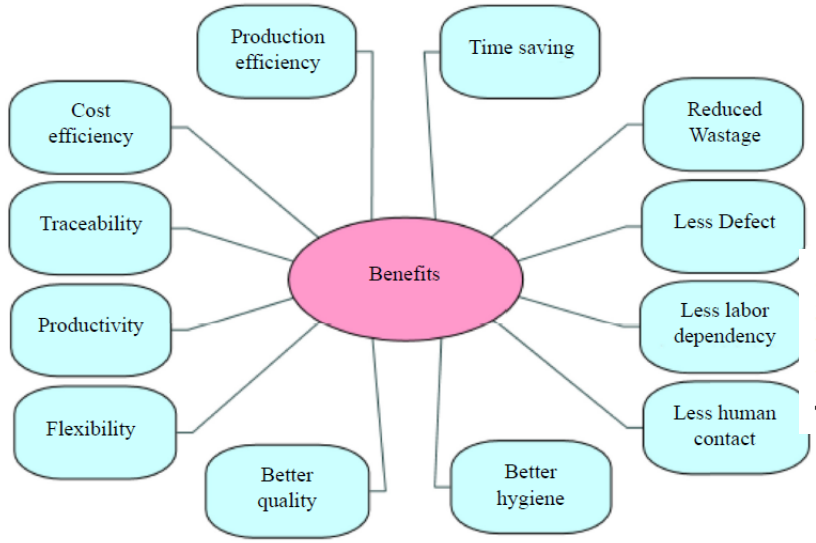

Figure 2.
Expected benefits of I4.0 adoption

Journal of Manufacturing Technology Management Vol. 33 No. 3, 2022 pp. 448-467, Emerald Publishing Limited , 1741-038X, DOI 10.1108/JMTM-03-2021-0111

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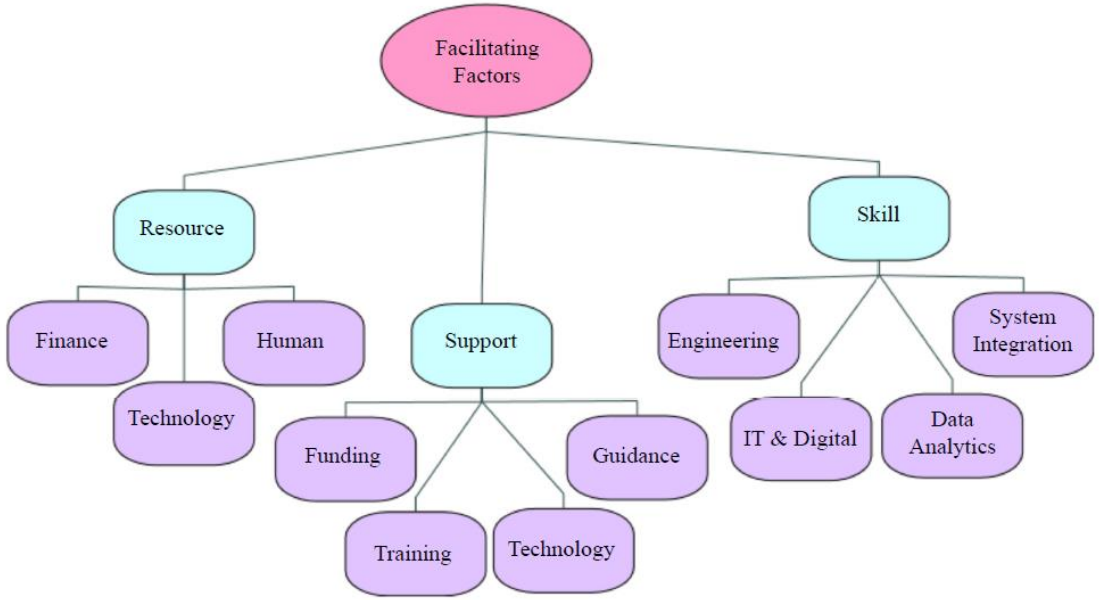


Figure 4.
Facilitating factors of I4.0 adoption

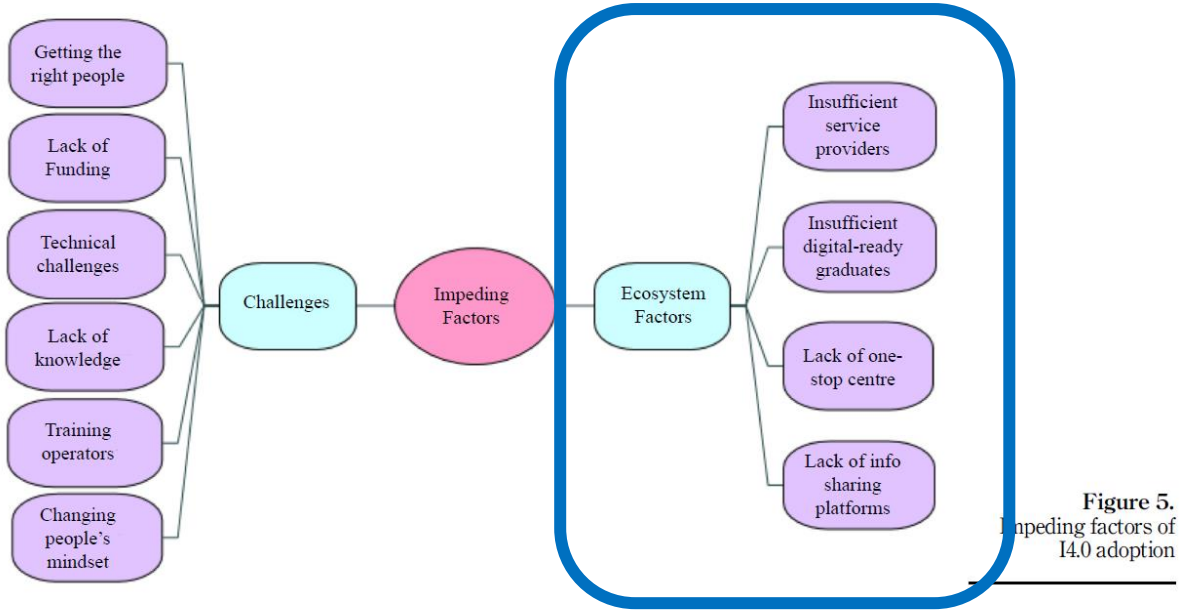


Figure 5.
Impeding factors of I4.0 adoption

Ecosystem for I4.0.

"These challenges include insufficient and inexperienced digital tech and service providers, an insufficient supply of **digital-ready graduates**, lack of **one-stop centres** and lack of **info-sharing avenues or platforms**:"

INDUSTRY4WRD READINESS ASSESSMENT (RA)

A **comprehensive programme** to help firms **assess their capabilities and readiness** to adopt Industry 4.0 technologies and processes, using a pre-determined set of indicators to understand their present capabilities and gaps

Government Incentives (2021- 2025)

- Government-funded Industry*4WRD* RA
- Tax deduction on expenditure of Industry4WRD RA fee : up to RM27,000

Outcome

- Identify the gaps and areas of improvement for Industry 4.0 adoption
- Develop feasible strategies and plans for intervention projects

INDUSTRY4WRD RA CRITERIA MODEL
*Manufacturing Sector

Focuses on people and the entire organisation.

Emphasis on strategies towards having a right set of workforce

Focuses on management system in running business operations, supply chain and product lifecycle.

Emphasis on smart and strategic public-private partnerships, security, sustainability and product co-creation.

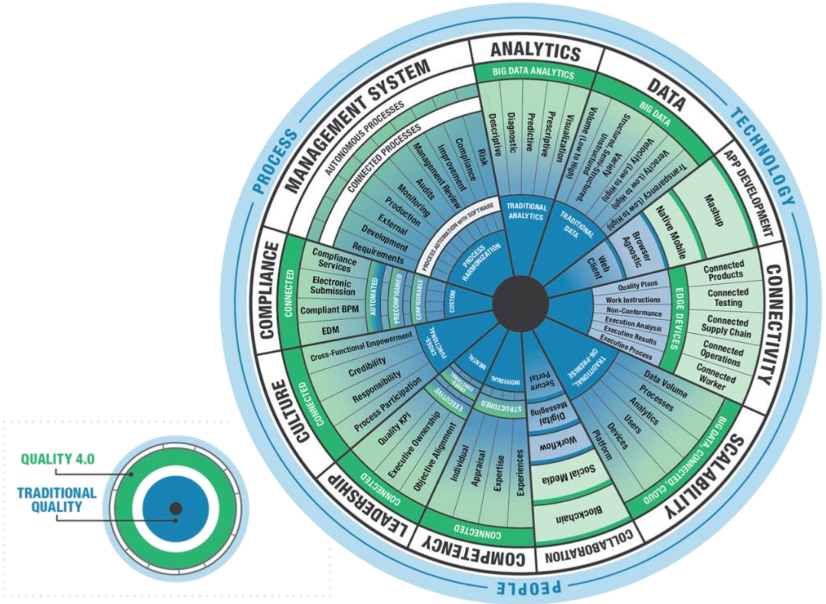
Focuses on the application of intelligent, connected and automated technologies.

Measured at three different layers of the business: Shop floor, enterprise and facility

*MRS Sector – Additional dimension

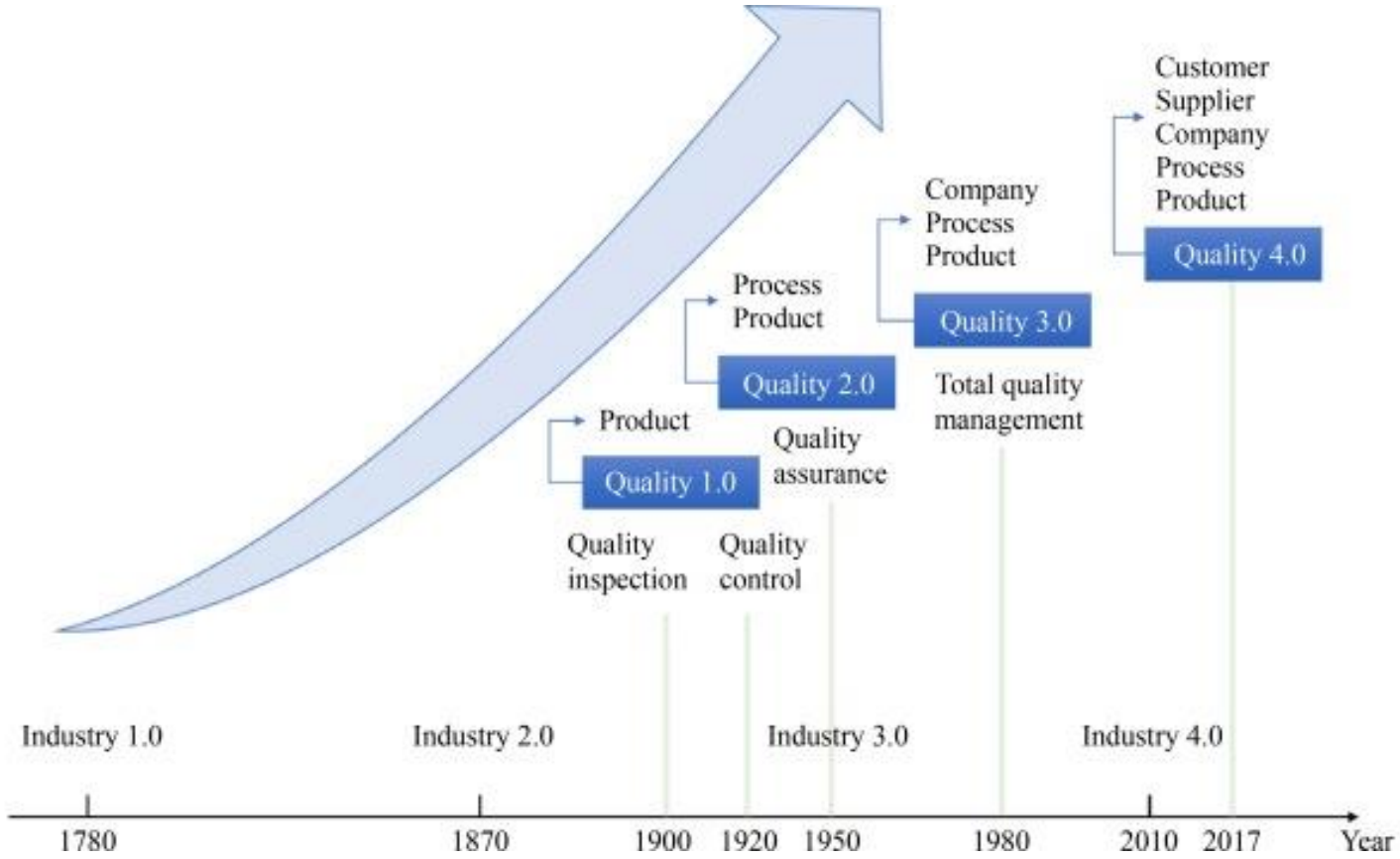
1. Technology (Work area)
2. Process (Resource Management, Service lifecycle management, service customisation)

Quality 4.0


ANALYTICS
BIG DATA ANALYTICS
DATA
TECHNOLOGY
APP DEVELOPMENT
CONNECTIVITY
SCALABILITY
COLLABORATION
COMPETENCY
LEADERSHIP
CULTURE
COMPLIANCE
MANAGEMENT SYSTEM
PROCESS
PEOPLE
QUALITY 4.0
TRADITIONAL QUALITY

Quality 4.0 – Current Research Issues

- How is Quality 4.0 being defined and understood?
- What are the CSFs for Quality 4.0?
- How to adopt Quality 4.0 technologies?
- How to measure success of Quality 4.0?
- Competencies of quality professional specific for Quality 4.0
- Enablers to Quality 4.0

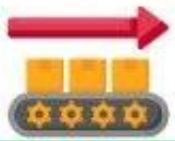


Hu-Chen LIU, Ran LIU, Xiuzhu GU, Miying YANG From total quality management to Quality 4.0: A systematic literature review and future research agenda
https://journal.hep.com.cn/fem/EN/10.1007/s42524-022-0243-z

Figure 1. Digital transformation from Quality 1.0 to Quality 4.0.

The Evolution of Quality 4.0

(With Industry 4.0)

	Industry 1.0	Industry 2.0	Industry 3.0	Industry 4.0
Period	18th Century (Prior to 1890)	19th Century (1890 to 1940)	Mid 20th Century (1940 to 1995)	Today (1995 - Today)
Enabling Technology	Steam power	Electricity	ICTs Electronics	Cyber systems, Internet of things (IoT),networks
Production System	Mechanical production	Mass production & assembly lines	Automation & networked production	Intelligent, flexible, distributed production
Quality Systems	**Quality 1.0**	**Quality 2.0**	**Quality 3.0**	**Quality 4.0**
	Self - inspection: • Productivity was priority • Measurement & Inspection. • Production volume over Quality • No focus on Waste • Work Conditions are not important	Inspection / control assurance/military standards • Maximizing Productivity • Minimum acceptance Quality Level were defined • Reduction of Scrap • Labor Performance	Software's for QMS, Quality improvement and planning • Standardization (ISO 9001) • Quality is Business Imperative • Focus on Customer Satisfaction • Continuous Quality Improvement	Continuos quality with real time data and IoT • Digitalization • Optimize Quality and Productivity • Process Design is Focused • Adaptive Learning • Cyber Physical Interaction

https://www.linkedin.com/posts/manickavasagam-natarajan_qaqc-lean-leansixsigma-activity-7104674508732600320-AE0B

INDUSTRY 1.0

New manufacturing processes, mechanization, water and steam power

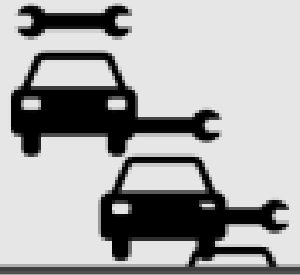
1760 - 1840

Emphasized standardization and inspection as mass production gained momentum

QUALITY 1.0

INDUSTRY 2.0

Electrical power, mass production/assembly line, more sophisticated machines.



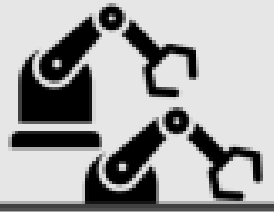
1890- 1940

Statistical quality control methods championed by figures like Deming and Juran post-World War II.

QUALITY 2.0

INDUSTRY 3.0

Electronics and IT (Information Technology) computers, programmable logic controller, Partial automation



1940-1995

Total Quality Management (TQM), focusing on a holistic organizational approach emphasizing employee involvement, customer satisfaction, and continuous improvement.

QUALITY 3.0

INDUSTRY 4.0

Interconnected technologies and smart devices. Smart and autonomous systems fueled by data and machine learning. Reduce human input as much as possible, machines learn to learn– Artificial Intelligence

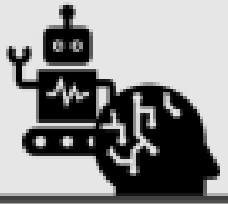
1995-present

Leverages digital technologies, automation, and data analytics to optimize quality management across industries.

QUALITY 4.0

INDUSTRY 5.0

Collaboration between humans and machines, Customization, Automation with a soul



2020-present

Social Oriented Quality, Systems develop empathy Needs drive availability Concern for all living beings

QUALITY 5.0

Quality 4.0 Definitions

Author(s)	Definition
Jacob (2017)	"Quality 4.0 certainly includes the digitalization of quality management" (p. 8) "Quality 4.0 does not replace traditional quality methods, but rather builds and improves upon them" (p. 8)
Radziwill (2018)	"Quality 4.0 is the name given to the pursuit of performance excellence during these times of potentially disruptive digital transformation" (p. 24)
Salimova *et al.* (2020)	". . .an adaptive ability of an object at all stages of the life cycle to meet the needs of a particular consumer on the basis of partnership with stakeholders and digital management of the value chain" (p. 486)
Zonnenshain and Kenett (2020)	". . .a framework for a quality discipline supporting the fourth industrial revolution. We propose to call it Quality 4.0" (p. 1)
Ramezani and Jassbi (2020)	"Quality "4.0" is a branch of the industry 4.0 (I4.0) movement associated with the digital transformation process connected with emerging technologies" (p. 5)
Sony *et al.* (2020)	"Quality 4.0 as such is so much more than technology. It is a new method by which digital tools can be used so that organizations' ability to consistently deliver high-quality products can be improved" (p. 781)
Escobar *et al.* (2021)	"Quality 4.0 is founded on a new paradigm based on empirical learning, empirical knowledge discovery, and real-time data generation, collection, and analysis to enable smart decisions" (p. 2320)

Table 6. Definitions for quality 4.0

Broday, E.E., (2022), The evolution of quality: from inspection to quality 4.0, International Journal of Quality and Service Sciences Vol. 14 No. 3, pp. 368-382, Emerald Publishing Limited 1756-669X DOI 10.1108/IJQSS-09-2021-0121

Quality 4.0 Concepts

The term “Quality 4.0” refers to the future of quality within the context of Industry 4.0 (ASQ, Quality 4.0).

The three aspects of quality “(a) quality of design, (b) quality of conformance and (c) quality of performance” needs are increasingly met **using improved technologies** such as “cyber physical systems (CPS), Internet of Things (IoT),robotic process automation (RPA), big data, artificial intelligence (AI) and cloud computing”.

Antony, J, et al, (2021), An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions, International Journal of Quality & Reliability Management, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-10-2021-0357

Quality 4.0 Concepts

The Quality 4.0 definition is evolving, and recent qualitative studies have defined Quality 4.0 as “the use of advanced technologies such as IoT, CPS, Cloud computing to design, operate and maintain adaptive, predictive, self-corrective, automated quality systems along with improved human interaction through quality planning, quality assurance, quality control and quality improvement to achieve new optimums in performance, operational excellence, and innovation to meet the vision, mission and goals of an organization.” (Antony et al., 2021).

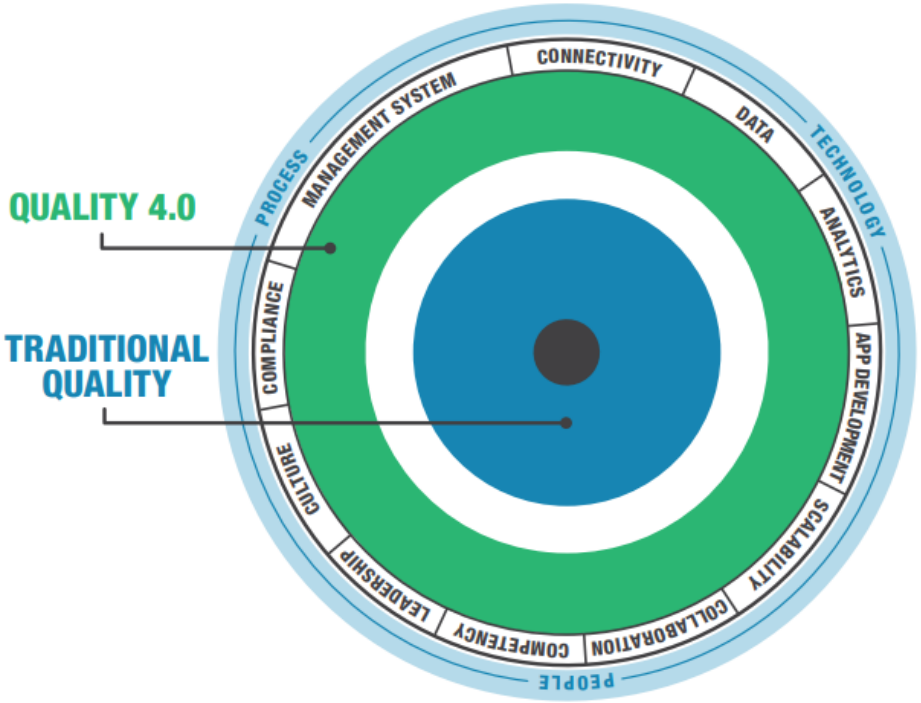
Antony, J, et al, (2021), An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions, International Journal of Quality & Reliability Management, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-10-2021-0357

What is Q 4.0?

- Digitalization of QM and the impact of digitalization on people, processes, and product
- Does not replace conventional quality methods, but instead builds on and improves them
- Digitalize QM by applying traditional and Industry 4.0 technologies (IIoT, advanced industrial analytics, cloud, digital twins, etc.) to improve quality monitoring and outcomes
- Quality 4.0 is quality data enhanced with other data sources such as manufacturing, machine sensors, supplier management, and product lifecycle data, to **derive new analytical insights to be used across the entire enterprise**

Transforming Quality

QUALITY 4.0 by LNS Research describes how manufacturers use modern technologies such as advanced analytics and digital connectivity to transform traditional quality and improve operational excellence; enabling enterprise efficiencies, innovation, performance, or strategic objectives.



https://www.inceptra.com/wp-content/uploads/2021/11/eBook-LNS-Research-Quality-4.0-The-Quality-Innovation-Foundry.pdf

Quality 4.0 conceptualisation and theoretical understanding: a **global exploratory** qualitative study

FINDINGS - provides theoretical base for Quality 4.0 body of knowledge in terms of an organisation's adoption, implementation challenges, and examples of Quality 4.0 application.

- the benefits and motivating factors for implementing, the Critical Success Factors, challenges, the organisational readiness factors
- the role of leadership in a Quality 4.0 deployment
- the skills required by future Quality 4.0 professionals in terms of hard skills, soft skills and a curriculum for educating future quality management professionals
- respondents cited predictive analytics, sensors and tracking, and electronic feedback loops the most critical technologies for driving Quality 4.0

Antony, J., McDermott, O. and Sony, M. (2021), "Quality 4.0 conceptualisation and theoretical understanding: a global exploratory qualitative study", The TQM Journal, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/TQM-07-2021-0215

An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions (Antony, et al, 2021)

Readiness factor	Mean scores	Normalization
Top management support	4.00	1.00
Leadership	3.94	0.91
Organizational culture towards Quality 4.0	3.86	0.80
Customer readiness	3.83	0.74
Knowledge and awareness on Quality 4.0	3.80	0.70
Quality 4.0 vision and strategy	3.73	0.61
Supplier readiness	3.59	0.41
Trainings and rewards	3.30	0.00

Table 8. Overall readiness factors

Readiness factor	Mean scores	Normalization
Top management support	4.18	1.00
Leadership	4.08	0.87
Organizational culture towards Quality 4.0	3.97	0.72
Customer readiness	3.96	0.70
Quality 4.0 vision and strategy	3.93	0.67
Knowledge and awareness on Quality 4.0	3.87	0.58
Supplier readiness	3.68	0.32
Trainings and rewards	3.45	0.00

Table 9. Readiness factors for large enterprises

International Journal of Quality & Reliability Management

0265-671X
DOI 10.1108/IJQRM-10-2021-0357

Antony, et al, (2021), An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions International Journal of Quality & Reliability Management, Emerald, 0265-671X DOI 10.1108/IJQRM-10-2021-0357

Table 10.
Readiness factors for small enterprises

Readiness factor	Mean scores	Normalization
Knowledge and awareness on Quality 4.0	3.56	1.00
Organizational culture towards Quality 4.0	3.50	0.92
Leadership	3.49	0.91
Top management support	3.44	0.83
Customer readiness	3.39	0.76
Supplier readiness	3.32	0.67
Quality 4.0 vision and strategy	3.05	0.30
Trainings and rewards	2.83	0.00

Table 11.
Readiness factors difference between large and SMEs

Readiness factor	LE	SME	*t*-test	*p*-value
Top management support	4.18	3.44	2.490	0.014
Quality 4.0 vision and strategy	3.93	3.05	3.091	0.002
Leadership	4.08	3.49	2.097	0.038
Trainings and rewards	3.45	2.83	2.278	0.024
Knowledge and awareness on Quality 4.0	3.87	3.56	1.053	0.294
Organizational culture towards Quality 4.0	3.97	3.50	1.627	0.106
Customer readiness	3.96	3.39	1.936	0.055
Supplier readiness	3.68	3.32	1.181	0.240

Table 12.
Critical readiness factor in manufacturing sector

Readiness factor	Mean scores	Normalization
Top management support	3.91	1.00
Leadership	3.79	0.85
Organizational culture towards Quality 4.0	3.73	0.78
Knowledge and awareness on Quality 4.0	3.69	0.72
Customer readiness	3.68	0.70
Quality 4.0 vision and strategy	3.60	0.61
Supplier readiness	3.54	0.53
Trainings and rewards	3.12	0.00

Table 13.
Critical readiness factor in service sector

Readiness factor	Mean scores	Normalization
Leadership	4.33	1.00
Top management support	4.24	0.84
Customer readiness	4.20	0.78
Organizational culture towards Quality 4.0	4.19	0.76
Knowledge and awareness on Quality 4.0	4.06	0.54
Quality 4.0 vision and strategy	4.05	0.53
Trainings and rewards	3.77	0.06
Supplier readiness	3.74	0.00

- Importance of organizational readiness factors for the successful adoption of Q4.0,
- Can be used as indicators to understand readiness of an organization to implement Q4.0
- Organizations not ready will have tough time implementing Q4.0
- Readiness factors highly beneficial to senior quality professionals - both manufacturing and service who would like to embark on the journey of Q4.0.

Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research

Topic	Issue
Creating value within the company through quality (big) data, analytics and AI	Automated collection and sharing of the right data (where, what, how, to whom)
	Using analytics, predictive software and AI for problem-solving and decision-making process
Developing Quality 4.0 skills and culture for quality people	Acquiring expertise to collect, analyse and interpret (big) data, taking actions, for both employees and professionals
	Sustaining and promoting Quality 4.0 culture
Customer value co-creation	Digital servitization
	Automatically streaming (big) data from the customer to design and production
	Improving customer relations and experience through CPS, CRM, AI, social media
CPS and ERP for quality assurance and control	Monitoring product state and route
	Automatically collecting data and information concerning inspections and audits results, non-conforming product, calibration results
	Managing data through PLM and MES software
	Automating document control process

Table 5.
Relevant Quality 4.0 topics and issues emerging from the SLR

Main Issues
1. Digitalization of Quality Management Processes and Activities
2. Competencies for Quality Personnel in digitalization technologies

Chiarini,A., (2020) Industry 4.0, quality management and TQM world. A systematic literature review and a proposed agenda for further research, The TQM Journal, Vol. 32 No. 4, pp. 603-616, Emerald Publishing Limited DOI 10.1108/TQM-04-2020-0082

Critical success factors for the effective implementation of Quality 4.0 in more expansive organisations (Large companies)

1. Handling big data
2. Improving prescriptive analytics
3. Using Quality 4.0 for an effective vertical, horizontal and end-to-end integration
4. Using Quality 4.0 for strategic advantage
5. Leadership in Quality 4.0
6. Training in Quality 4.0
7. Organisational culture for Quality 4.0
8. Top management support for Quality 4.0

Sony, M., Antony, J. and Douglas, J.A. (2020), “Essential ingredients for the implementation of quality 4.0: a narrative review of literature and future directions for research”, The TQM Journal. DOI: 10.1108/TQM-12-2019-0275.

Competencies of quality professionals in the era of industry 4.0: a case study of electronics manufacturer from Malaysia

- To investigate the competencies required for quality management professionals to meet needs of industry 4.0
- To determine how companies adapt to be relevant in the industry 4.0 environment

Method : 64 quality professionals with a response rate of 96.88%. Interview to 3 decision-makers from critical areas in the electronics manufacturer
- finance, operations and talent development

4 RQ

(1) How are the changing technological trends expected to impact the future role of quality in industry 4.0?

(2) What are the competencies gap between current and future roles of quality professionals?

(3) What are the views and practices related to quality roles?

(4) How can the gaps identified be closed to meet the quality challenges of industry 4.0?

K. Sumitha P.N. Kannan and Alaa Garad (2021), Competencies of quality professionals in the era of industry 4.0: a case study of electronics manufacturer from Malaysia, International Journal of Quality & Reliability Management Vol. 38 No. 3, 2021 pp. 839-871K

Their Findings

- Quality professionals will need **technical competencies** to interpret large amounts of data from processes to make strategic decisions
- **Methodological competencies** required to use data to identify source of problems, to access reliable sources of learning and the ability to use new tools for solving complex problems efficiently
- **Social competencies** in communications across multi-sites, suppliers and customers in new collaborative virtual platforms, ability to retain tacit and explicit knowledge, in a decentralized environment
- **Personal competencies** required will be the ability to work in a flexible workplace and time and more frequent work-related changes.

Conclusion

Quality professionals lack awareness of new roles in industry 4.0 - new technology is not implemented by (local) quality professionals but by the innovation team based in Singapore headquarters

Difficulty when you are a foreign subsidiary level – dependent on headquarter decision

Table 2.
Recommendation for the competency gap solutions

Competence	What is required	Suggested actions to be taken	Responsibility
Technical skills			
1. Increased job knowledge due to automated processes	Require knowledge of the automated processes	Awareness training, exposure to new technology by attending exhibitions, supplier demo, etc.	Top management and Innovation team
2. Strategic role as change agent and to identify value creation opportunities	Require knowledge from processes to align with business goals and objectives	Audit with new big data capability to have access to enterprise level data Corbin (n.d.)	Quality department/IT department
3. Higher technical and media skills for new technologies	Require knowledge of media tools	Machine/equipment suppliers to conduct on-site training Benešová and Tupa (2017, p. 2198)	Supplier
4. Awareness of data security	Require knowledge of IT and how data security is breached	Training on cyber security and data integrity and risk management Tupa *et al.* (2017, p. 1224)	IT department/ Quality department
Methodological skills			
1. Ability to solve complex problems by examining large amounts of data	Require knowledge to analyse big data in order to interpret and solve	Training in big data analysis using new tools Benešová and Tupa (2017, p. 2198)	Supplier
2. Reliable sources for continuous learning	Require access to the new knowledge	Have a personal assistant/ mobile device to retrieve relevant information and/or AR Gorecky *et al.* (2014, p. 292) and Gaskil (2017, p. 11)	Quality department/ Innovation team
3. Ability to solve complex problems efficiently, with new tools	Require capability for efficient problem-solving, with new advanced tools (analytics and algorithms)	Training to maximize value using new tools and software, by supplier Benešová and Tupa (2017, p. 2198) and Sung (2018, p. 41)	Supplier/Training department

Table 2.
Recommendation for the competency gap solutions

Competence	What is required	Suggested actions to be taken	Responsibility
Personal skills			
1. Ability to be flexible in work and time due to virtual work environment	Require work regulation to have work–life balance	Drafting of work regulation for industry 4.0 environment Hecklau *et al.* (2016, p. 3)	Human Resource
2. Be motivated to adapt to frequent work related changes	Require quality managers to motivate their teams and manage diverse employees, even virtually	Training for managers to change management style from power-driven to value-driven Erol *et al.* (2016, p. 14)	Training department
Social skills			
1. Increased virtual communication capabilities	May require knowledge of new virtual tools across platforms and value chains	Training in new virtual tools and platforms Benešová and Tupa (2017, p. 2198)	Training department/ supplier
2. Effective knowledge retention	Require effective knowledge sharing and storage	Centralizing data from all components of a smart factory in a quality intelligence solutions Lyle (2017, p. 8)	IT department
3. Ability to make decisions as leaders in decentralized environment	Require to read and understand process information from machines	Machine/equipment suppliers to conduct on-site training Benešová and Tupa (2017, p. 2198)	Supplier

Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda

Purpose – Quality 4.0 (Q4.0) is related to quality management in the era of Industry 4.0 (I4.0). It concentrates on digital techniques used to improve organizational capabilities and ensure the delivery of the best quality products and services to its customer.
Aim of this research : to examine the vital elements for the Q4.0 implementation.
Design/methodology/approach – Literature review carried out to analyze past studies in this emerging research field

Ramadas Thekkoote, (2022), Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda, International Journal of Quality & Reliability Management Vol. 39 No. 6, pp. 1368-1384, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-07-2021-0206

Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda

Findings

Identified ten factors that contribute to the successful implementation of Q4.0.

(1) Data
(2) Analytics
(3) Connectivity
(4) Collaboration
(5) Development of apps
(6) Scalability,
(7) Compliance,
(8) Organization culture
(9) Leadership and
(10) Training for Q4.0.

Originality/value

= a new understanding of factors of successful implementation of Q4.0 in the digital transformation era can assist firms in developing new ways to implement Q4.0.

Ramadas Thekkoote, (2022), Enabler toward successful implementation of Quality 4.0 in digital transformation era: a comprehensive review and future research agenda, International Journal of Quality & Reliability Management Vol. 39 No. 6, pp. 1368-1384, Emerald Publishing Limited, 0265-671X DOI 10.1108/IJQRM-07-2021-0206

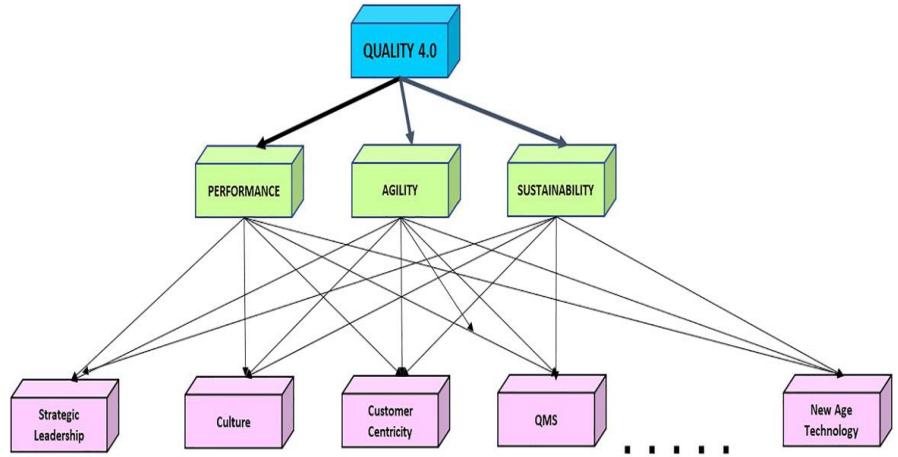
Quality 4.0 – understanding the criticality of the dimensions using the analytic hierarchy process (AHP) technique

Quality 4.0 refers to the digitalization of quality work in the context of Industry 4.0.

Objectives of the research are to:

(1) Identify the **dimensions of Quality 4.0** that would help in understanding of the requirements of Quality 4.0 implementation in organizations

(2) Prioritize these dimensions in terms of how they contribute to the establishment of Quality 4.0 in organizations using the analytic hierarchy process (AHP) technique



G.S. Sureshchandar, (2022), Quality 4.0 – understanding the criticality of the dimensions using the analytic hierarchy process (AHP) technique, International Journal of Quality & Reliability Management, Vol. 39 No. 6, pp. 1336-1367 © Emerald Publishing Limited 0265-671X DOI 10.1108/IJQRM-06-2021-0159

Quality 4.0 – understanding the criticality of the dimensions using the analytic hierarchy process (AHP) technique

Findings

- 12 dimensions contribute to outcome indicators such as organizational performance, agility and sustainability
- Although technology vital for Quality 4.0, elements of traditional quality such as leadership, quality culture, customer focus, quality systems, compliance, competence, analytical thinking, data-driven decision making, etc. are mandatory for the transformation journey

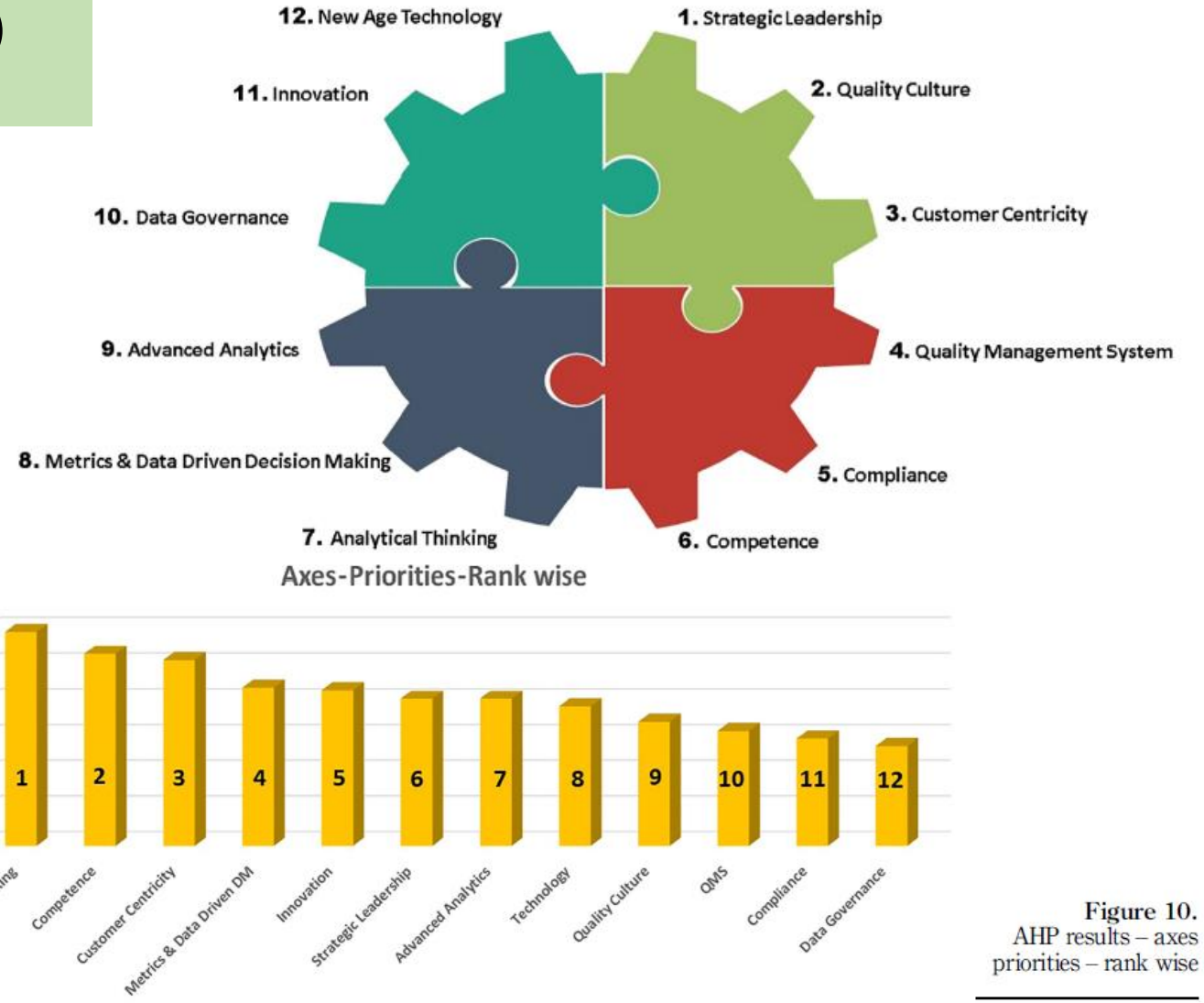


Figure 10.
AHP results – axes priorities – rank wise

G.S. Sureshchandar, (2022), Quality 4.0 – understanding the criticality of the dimensions using the analytic hierarchy process (AHP) technique
International Journal of Quality & Reliability Management, Vol. 39 No. 6, pp. 1336-1367 © Emerald Publishing Limited 0265-671X DOI 10.1108/IJQRM-06-2021-0159

Journal of Intelligent Manufacturing (2021) 32:1679–1698
https://doi.org/10.1007/s10845-021-01783-2

Digitalization priorities of quality control processes for SMEs: a conceptual study in perspective of Industry 4.0 adoption

Gautam Dutta[1] · Ravinder Kumar[2] · Rahul Sindhwani[2] · Rajesh Kr. Singh[3]

Addressed the digitalization priorities of quality practices for Small and Medium Enterprises (SMEs) in perspective of adoption of Industry 4.0 technologies.

Authors observed that extensive literature available regarding quality and its relevance for continuous improvement, while research insights regarding **integration of quality practices in a digital environment are limited** and even if considered, they have not been studied holistically.

Quality management being at the core of customer focus for SMEs, objective of this research article is to formulate the recommended approaches for adopting digital technologies for quality processes in the PDCA cycle, while addressing the following questions:

- Which quality processes take priority to be digitally integrated for improved responsiveness?
- How to manage improvement projects integrated with product development and quality?
- How to effectively analyze deviations early in the product development cycles?
- How to manage data from design and process experimentations and decision criteria?
- How to efficiently execute inwards goods inspections to track suppliers?
- How to address customer complaints, plan improvement and achieve faster resolutions?

- Main objective of research is to establish a set of approaches to guide SMEs prioritize the quality processes that need to be digitalized and integrated to the design and manufacturing value chain

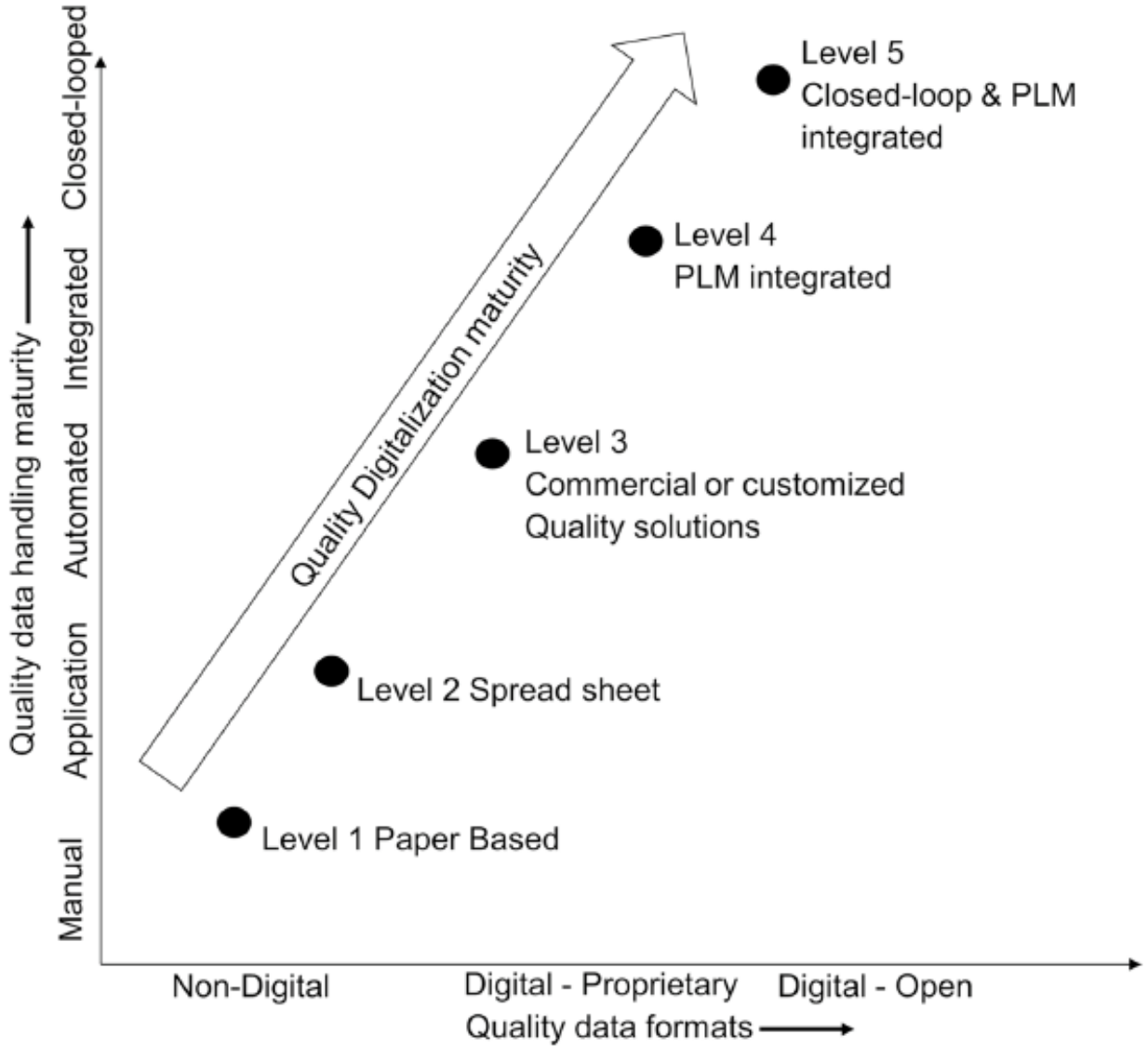


Fig 1 Quality adoption maturity matrix based on data handling and data formats

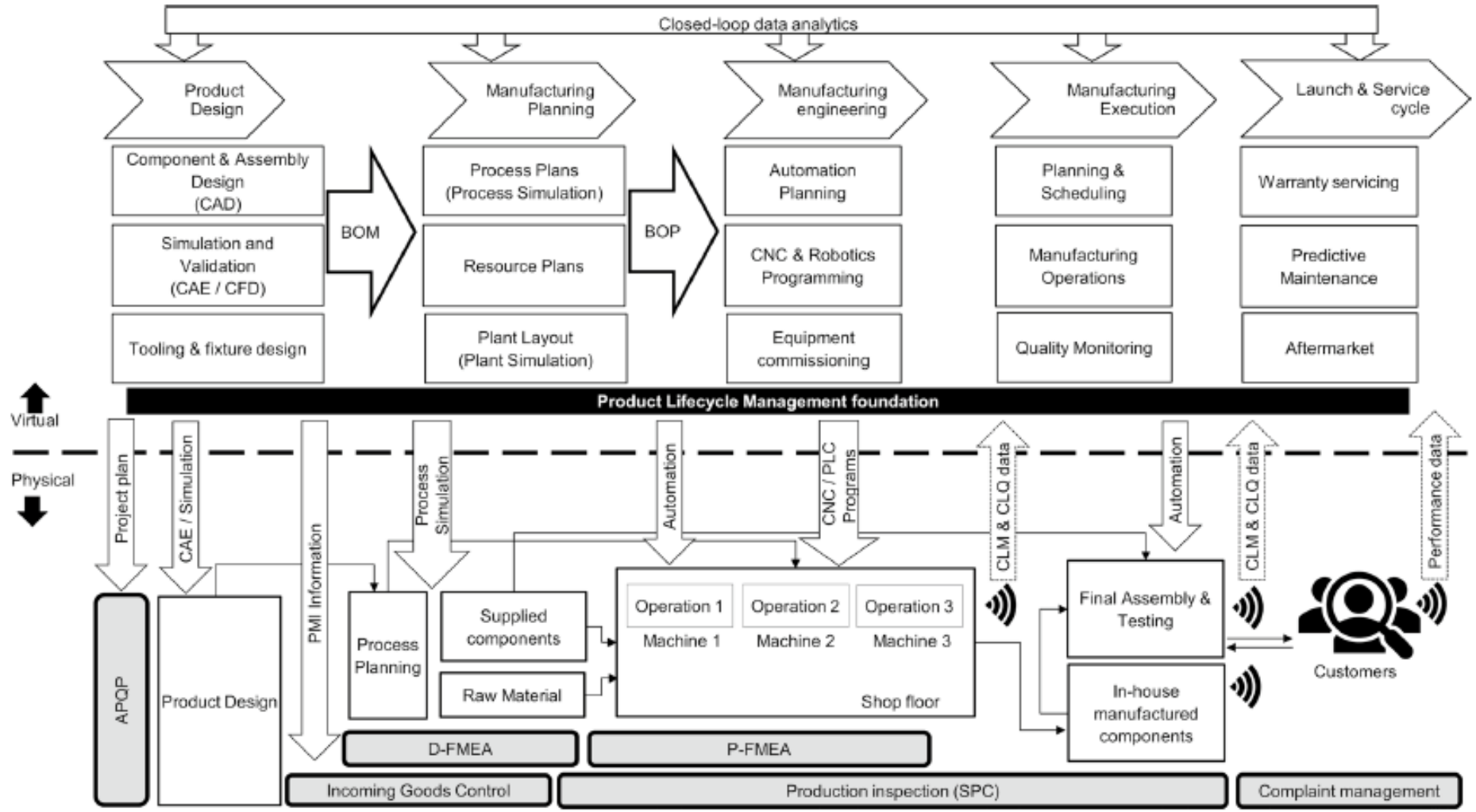


Fig. 4 Setup of a virtual and physical engineering value chain with overall quality processes (Dutta, et al (2021))

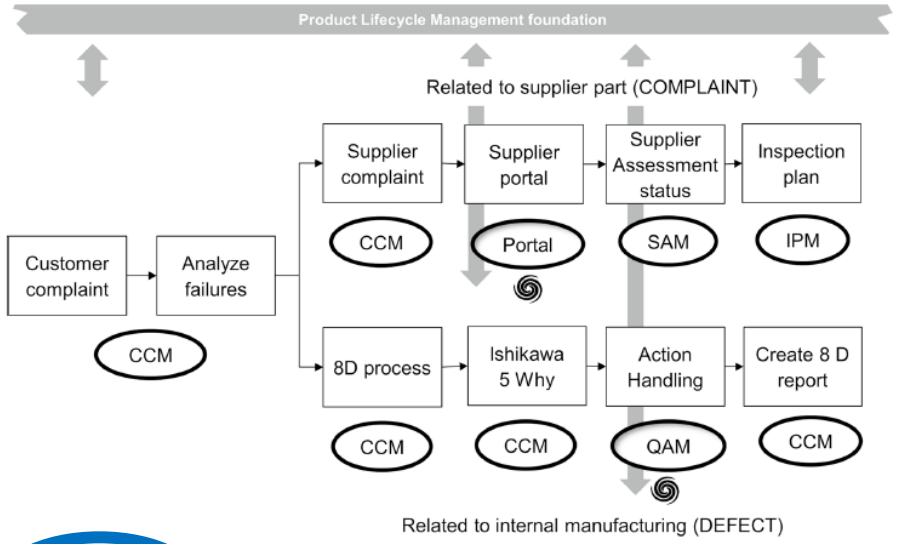


Fig. 8 Approach for ACT stage (*Source*: self-developed)

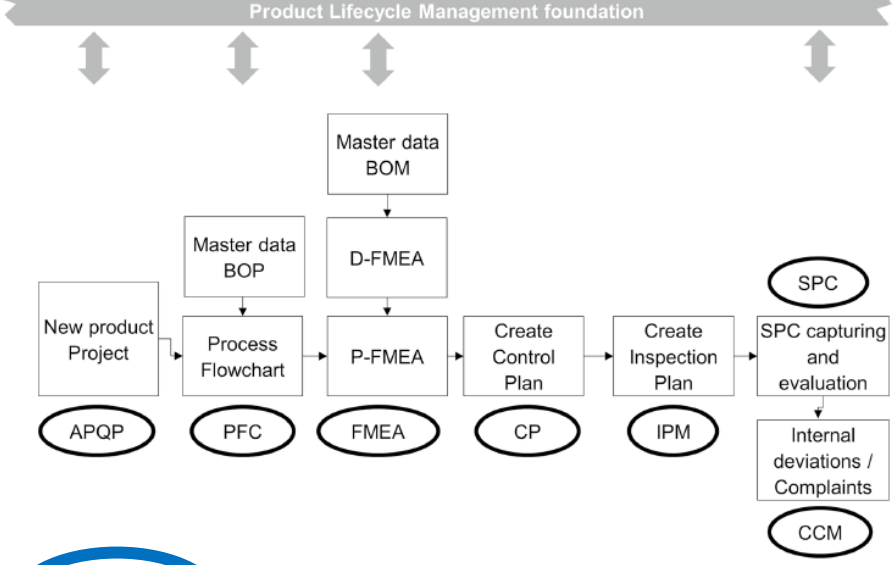


Fig. 5 Approach for PLAN stage (*Source*: self-developed)

Identified the PDCA quality processes those are related to digitalization ; can be integrated with the digital product development framework

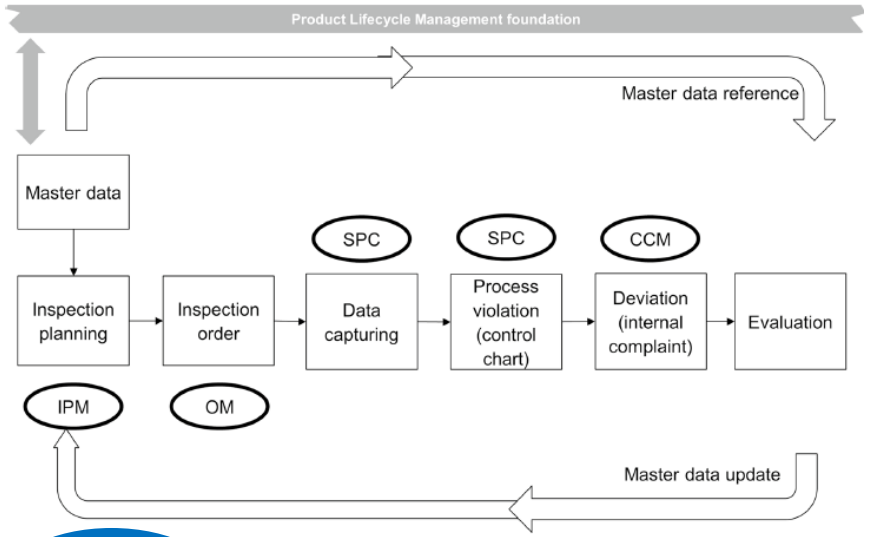


Fig. 7 Approach for CHECK stage (*Source*: self-developed)

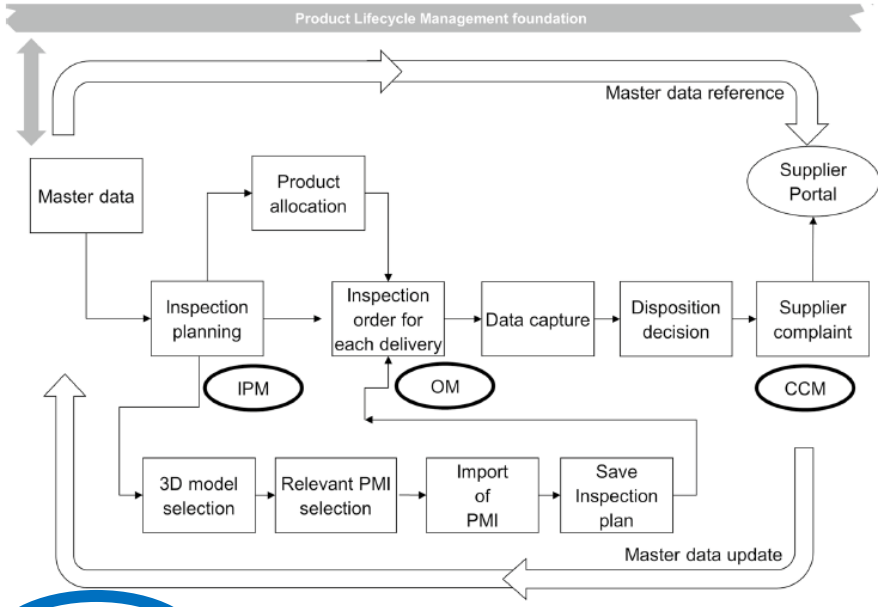


Fig. 6 Approach for DO stage (*Source*: self-developed)

Key findings based on proposed approaches for adopting digital quality processes:

1. SMEs need to adopt digitalization across the PDCA quality cycle
2. Digitalization of quality practices needs to be considered holistically across value chain
3. Five processes have been prioritized for digitalization based on their adoption maturity i.e. design for quality, compliance, incoming & outgoing goods control, statistical process control and complaint management

Strategy for QUALITY 4.0

- Quality 4.0 represents an opportunity to utilize Industry 4.0 technologies to realign quality functions with broader organizational strategy

- Need to develop Quality 4.0 strategy to address inefficiencies; e.g. lack of cross-functional ownership, ineffective communication, and fragmented traditional quality systems.

- Engage in strategic planning to explore how new technologies and the advantages they deliver – such as improved data transparency and high-quality data-driven insights to achieve a culture of excellence.

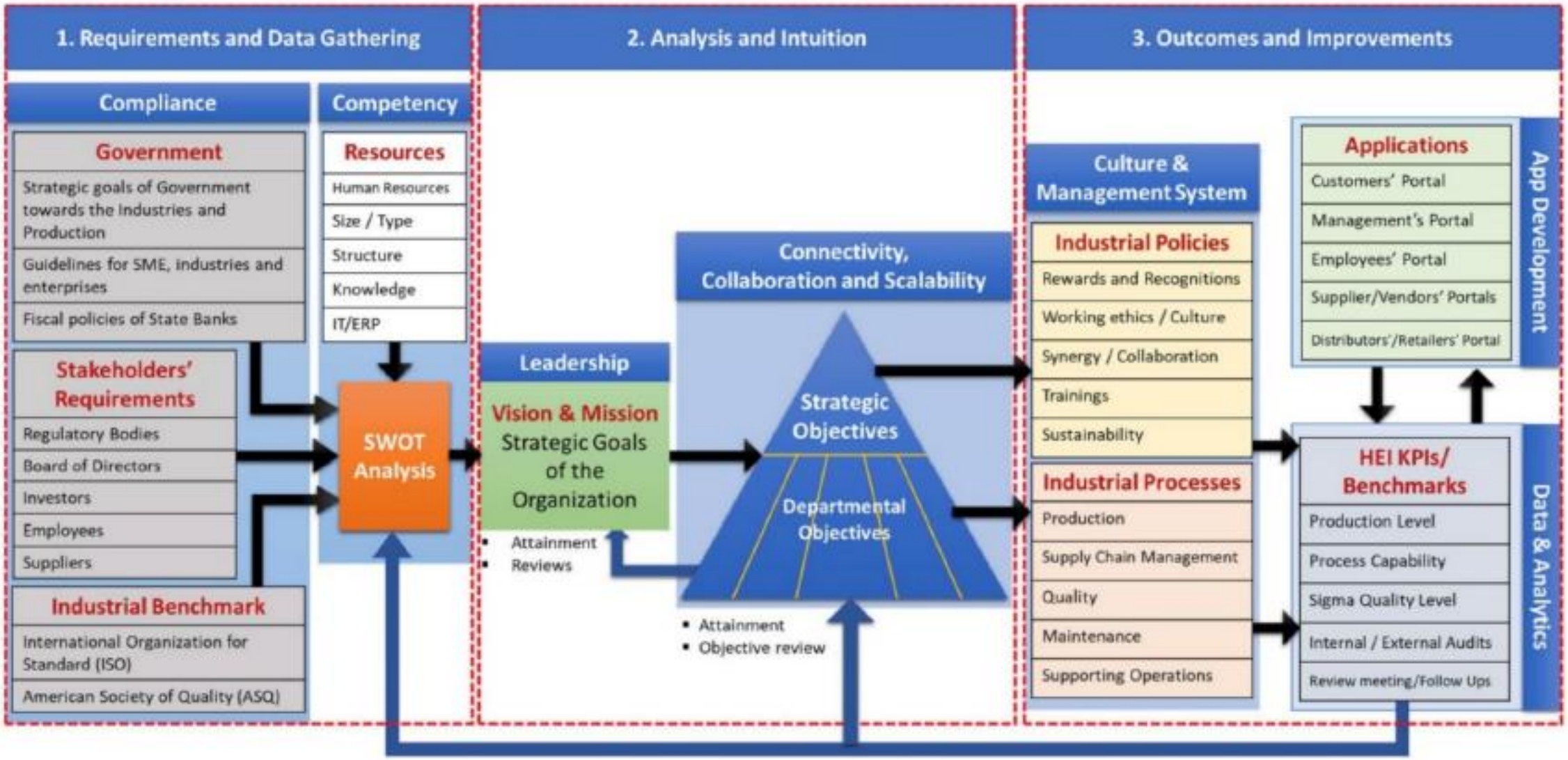
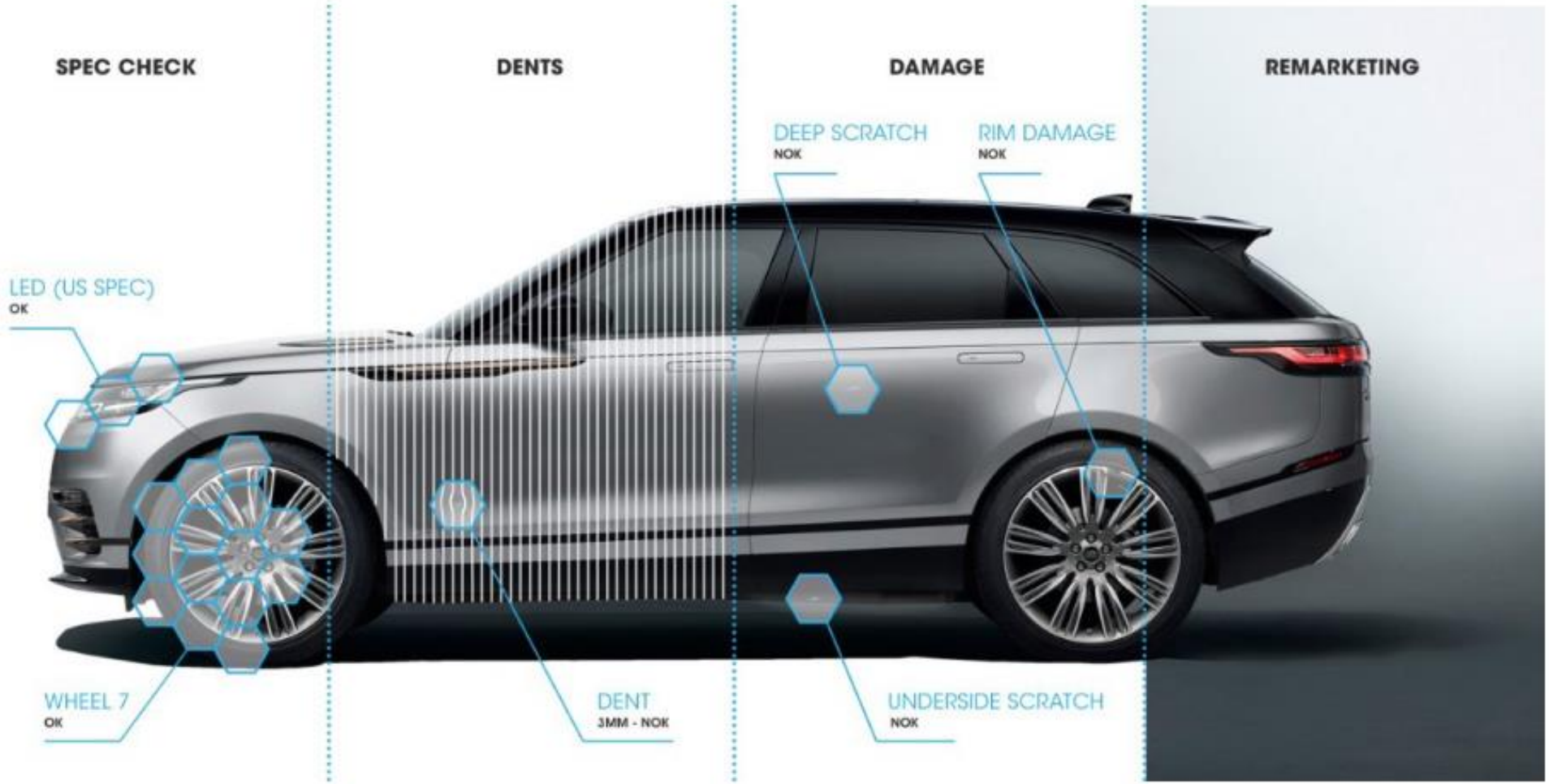


Figure 3. Proposed Quality 4.0 framework.

Zulqarnain, A.;Wasif, M.,Iqbal, S.A. Developing a Quality 4.0 Implementation Framework and Evaluating the Maturity Levels of Industries in Developing Countries. Sustainability **2022**, 14, 11298. https://doi.org/10.3390/su141811298

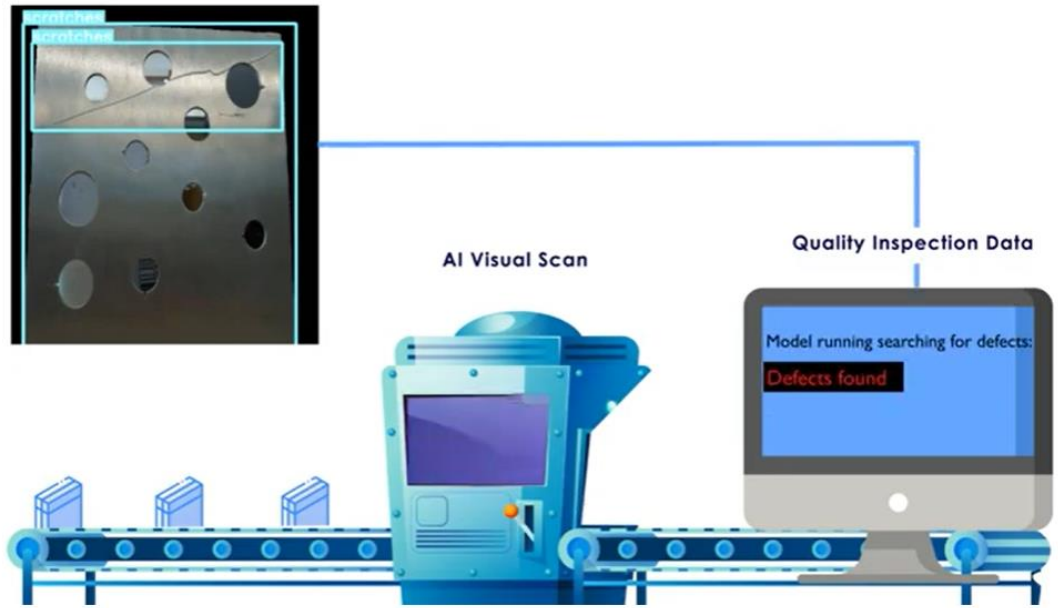
Quality 4.0 Tools Used by Automotive Companies

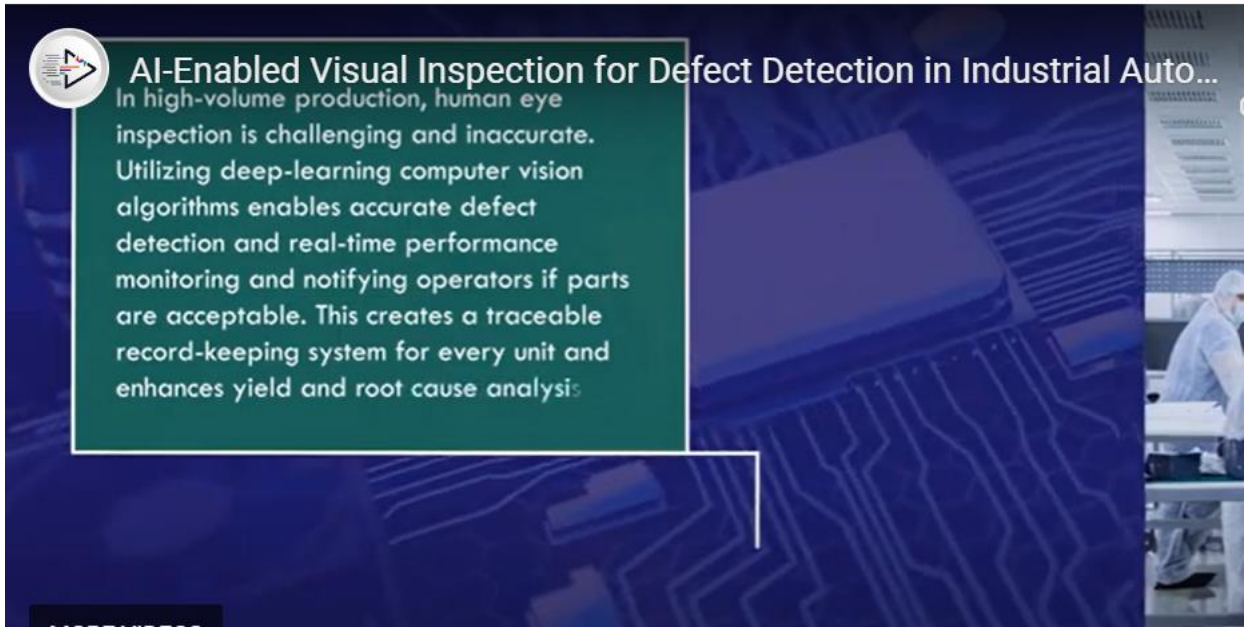
Company	Big Data & Predictive Analytics	AI & Machine Learning	IoT & Real-Time Monitoring	Digital Twin Technology	Smart Manufacturing & Automation	Cloud Computing & Collaborative Platforms	AR for Quality Assurance	CPS & Adaptive Manufacturing	Advanced Quality Control Techniques
General Motors (GM)	Predictive analytics for defect reduction	AI-powered vision systems for inspection							
Toyota			IoT sensors for real-time monitoring	Digital twins for process optimization					
Ford					Robotic automation for assembly	Cloud-based platforms for collaboration			
BMW		AI for predictive quality					AR glasses for quality assurance		
Mercedes-Benz (Daimler AG)								CPS for adaptive manufacturing	Non-destructive testing (NDT) techniques



Several automotive giants are already on the journey to digitise their inspection processes and achieve significant business benefits as a result

https://www.automotiveworld.com/articles/ai-reshapes-automated-vehicle-inspection/


scratches
scratches
AI Visual Scan
Quality Inspection Data
Model running searching for defects:
Defects found


AI-Enabled Visual Inspection for Defect Detection in Industrial Auto...
In high-volume production, human eye inspection is challenging and inaccurate. Utilizing deep-learning computer vision algorithms enables accurate defect detection and real-time performance monitoring and notifying operators if parts are acceptable. This creates a traceable record-keeping system for every unit and enhances yield and root cause analysis

Enabling digital transformations in industries and a society

Promotion of Digital Transformation (DX)

Digital Infrastructure Center
Information-technology Promotion Agency, Japan
Release Date:Jan 30, 2024

Enabling digital transformations in industries and a society

Architecture Guidelines

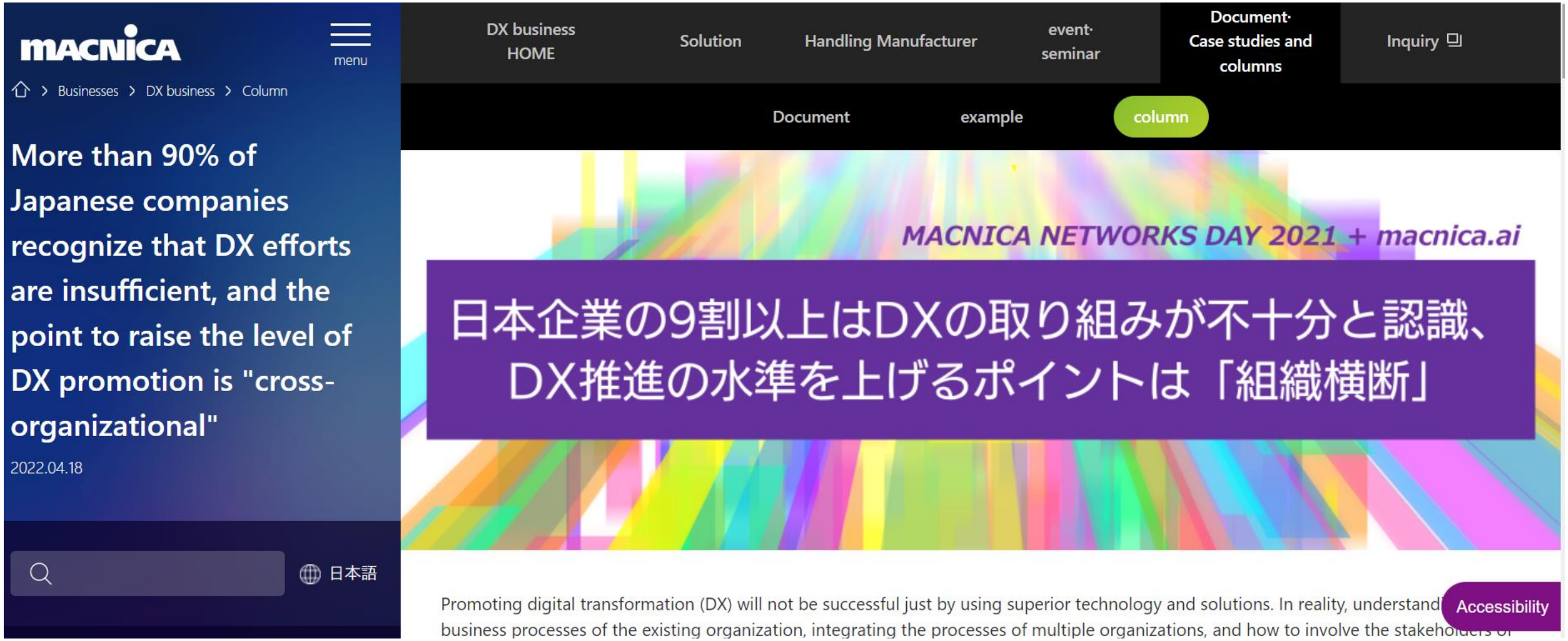
Promotion of Digital Transformation (DX)

Innovation in software development

Promotion of data utilization

Materialization of reliability in

https://www.ipa.go.jp/en/digital/dx.html



https://www.macnica.co.jp/en/business/dx/columns/141026/

Getty Images

Review Digital Revolution, Social Transformation through Digitalization

Current Status of Japan's DX/GX Policies and Company Activities for Their Simultaneous Promotion

March 25, 2024

AI IoT globalization ESG innovation

R-2023-073E

https://www.tokyofoundation.org/research/detail.php?id=967

Quality 4.0 Applications to enhance quality in manufacturing.

Link to the paper

RO1: To identify Quality 4.0 and its significant benefits;
RO2: to provide key aspects of Quality 4.0 for manufacturing development;
RO3: to identify major elements associated with Quality 4.0 in the manufacturing domain;
RO4: to identify significant enablers of Quality 4.0 for enhancing manufacturing scenario;
RO5: to identify and discuss Quality 4.0 applications to enhance quality in manufacturing

Mohd Javaid, Abid Haleem, Ravi Pratap Singh, Rajiv Suman, (2021), Significance of Quality 4.0 towards comprehensive enhancement in manufacturing sector, Sensors International, Vol 2, 100-109

WEBSITES OF AI APPLICATION IN QUALITY INSPECTION - MANUFACTURING

https://www.linkedin.com/pulse/global-business-impact-ai-visual-inspection-defect/

https://www.automotiveworld.com/articles/ai-reshapes-automated-vehicle-inspection/

https://www.assemblymag.com/articles/96075-ai-based-vision-technology-aids-vehicle-inspection

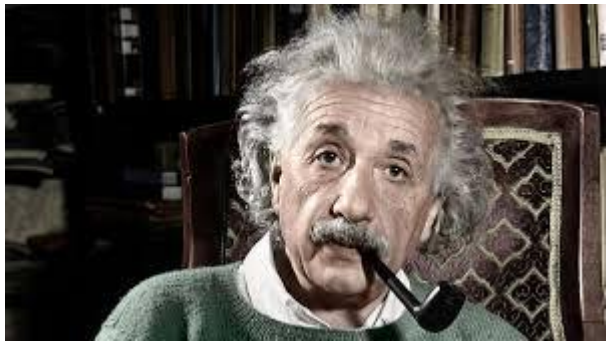
https://www.assemblymag.com/articles/96075-ai-based-vision-technology-aids-vehicle-inspection

https://saxon.ai/blogs/detect-defects-precisely-using-ai-visual-inspection-for-manufacturing/

https://lincode.ai/blog.php?id=69

https://nocamels.com/2022/03/volvo-ai-automate-vehicle-inspection-systems/

“Without changing our patterns of thought, we will not be able to solve the problems that we created with our current patterns of thought.”
~Albert Einstein



“Be a yardstick of quality. Some people aren’t used to an environment where excellence is expected.” Steve Jobs

“Quality is never an accident; it is always the result of high intention, sincere effort, intelligent direction and skillful execution; it represents the wise choice of many alternatives.” ~William A. Foster

Conclusions

- Abundant opportunities for implementing Q 4.0 and Ind 4.0 Tools and Technologies
- Need to update and upgrade skills and knowledge in digitalization – digital design, analytics, smart inspection systems, real-time inspection experts, etc.
- Creation of Local Platforms for Sharing Best Practices and Implementation Method (especially Small Medium Enterprise)
- Targeted Incentives and Financial Support may be needed for Malaysian SMEs
- Need to Update and Upgrade Graduates Digital Knowledge
- Curriculum to Focus on Digital Industrial Engineering + AI Based Quality Control, + other IR 4.0 technologies.

どうも ありがと
ございました

Domo arigato gozaimashita.